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A Lynx Management Strategy for British Columbia

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A LYNX MANAGEMENT STRATEGY FOR BRITISH COLUMBIA

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The lynx lives on rabbits, follows the rabbits, thinks rabbits, tastes likes rabbits, increases with them, and on their failure dies of starvation in the unrabbited woods.

- Ernest Thompson Seton, 1912 -

PART 1: SUMMARY STATEMENT

INTRODUCTION

There have been no significant population monitoring or research projects on lynx in British Columbia. However, the species is biologically uniform throughout its nearly cross- continental North American range, and findings from other areas are believed to be applicable. Following paragraphs highlight the major features of lynx biology, human use, and management, as documented in a detailed literature review and annotated bibliography, prepared separately.

THE 10-YEAR CYCLE

Records of lynx pelt sales since the early 1800's indicate a distinct cycle of abundance, with peaks approximately every 10 years. Harvest peaks do not occur in all areas at the same time, and do not always reach the same levels. Further, local peaks may result mostly from reproduction in some areas and from immigration in others.

In British Columbia, recent peaks have been in the third year of each decade. The 1962-63 peak was the highest on record, producing over 12 500 pelts, followed in the next cycle by a double peak (1972-73 and 1973-74) each with over 8500. The most recent peak (1982-83) was lower, with a harvest of about 6300 animals. The pattern for the last three cycles has been similar throughout western Canada, and the decline in the 1980's has caused some management concern.

Despite local, regional, and temporal differences, lynx cycles appear to have one unifying characteristic-- their relationship to the 10-year cycle of the snowshoe hare. That relationship is implied in the opening quote from the naturalist, E.T. Seton. Hares have been by far the most important food in all areas and seasons studied, and the evidence now available indicates that lynx are largely dependent, at all stages of the cycle, on that one prey species.

Therefore, most aspects of life history, population dynamics, and management of lynx are best expressed and considered in relation to patterns and trends of hare abundance.

LIFE HISTORY AND POPULATION DYNAMICS

When hares are abundant, adult lynx may be relatively secure, maintaining weight, condition, high pregnancy rates, and large litter sizes, all within well-defined home ranges and with minimal activity and effort. Adequately nourished kittens survive well and develop quickly, such that females may produce litters in their first year. With such productivity, and apparently lacking any regular non-nutrition related source of natural mortality, lynx populations have a large potential for increase.

When hare numbers decline, the nutritionally dependent lynx enter a period of relative stress, which may be manifested at the individual or population level by some or all of the following symptoms:

- Reduced physical condition.
- Increased activity and movements.
- Increased home range size or, in some cases, abandonment of home ranges.
- Long distance dispersal and attendant local "irruptions".
- Decreased productivity, especially among yearlings.
- Poor survival of kittens.
- Starvation of at least some adults.

TRAPPING MORTALITY

Evidence from tagging indicates that a large proportion of lynx mortality in many areas is human caused, mostly from trapping. However, not all animals are equally trappable. Again, nutritional factors play an important role. Animals that respond to local or cyclic food shortages by increasing activity and movements are more likely to encounter trap sets, and animals that are hungry and/or in poor condition are probably less likely to be cautious at baited sets. There is evidence that vulnerability to trapping may also vary with age, sex, winter severity, stage of the season, and trapping method.

Peak lynx harvests may reflect maximum insecurity of the population, following hare declines, while the lowest harvests may result from low overall numbers and/or low average vulnerability of the remaining population. Trapping mortality may largely replace natural mortality in some areas and some stages of the cycle, and may be additive to it in others.

The management significance of mortality as determined from harvest records has been difficult to determine, because it has not been possible to document the nature and extent of survival, either with or without trapping.

THE LYNX MANAGEMENT PROBLEM

A major consideration in lynx management in recent years as been the very high pelt value, which has both positive and negative aspects. On the positive side, the value of the 1980's peak harvest in British Columbia, at almost $2 million, was more than 10x higher than the record high harvest in the 1960's, and constituted almost one-half of the total B.C. fur revenue in that year.

Although such figures confirm the present value and importance of the animal to society, there is widespread concern that, stimulated by individual pelt prices of $1000 or more, continued intense harvest pressure during the low recruitment and low population stages of the lynx cycle will prevent or greatly reduce subsequent increases. Indeed, it is feared that reduced harvests in most areas in the 1980's, as compared to those in the previous two cycles when prices were lower, may reflect such overexploitation.

HARVEST MANAGEMENT

It is apparent that a "tracking strategy" is the most appropriate for managing harvests of the cyclic lynx, decreasing harvest pressure during the period of low population and recruitment, and increasing it when population performance improves.

Present (mid-cycle) lynx trapping regulations in western North America include complete closures where the overexploitation problem has been perceived to be the greatest, i.e. in all or portions of the Prairie provinces and in an accessible area of Alaska. Most areas, including B.C., have also shortened seasons in recent years, and trapline quotas have been set in remaining open season areas of Alberta and Manitoba.

There is evidence that lynx harvest patterns are more stable in British Columbia than on the Prairies, possibly because it supports more inaccessible lynx "refuges" in its extensive mountain habitats. It is therefore expected that some opportunity for harvesting can be

preserved in B.C. even during the population low.

Present recommendations call for further shortening the season in the north, maintaining a uniform, 3-month season (15 Nov. - 15 Feb.) throughout the province, and initiating trapline quotas in 1994-95, two years after the next expected harvest peak. Because harvest data are needed to better describe lynx distribution and cycling patterns in the province, and because altering seasons may affect harvest characteristics, subsequent harvest regulation will be primarily by increase or decrease of quotas.

POPULATION MONITORING

A tracking strategy requires knowledge about population status, therefore it is recommended that the present trapline-based harvest data system and pelt examination program be intensified, and that the monitoring program be expanded to include analysis of carcass samples, an annual trapper questionnaire on wildlife population trends, and selected snowshoe hare trend surveys.

Trapper cooperation is a vital ingredient in the long-term lynx management program. In addition to complying with regulations and providing reliable information, as required, trappers may be able to enhance lynx populations during the cyclic low by protecting remote refugia on their traplines, minimizing use of non-selective trapping methods such as "blind" sets and trail snares, live-releasing adult females, and practicing local habitat improvement.

HABITAT MANAGEMENT

The most neglected aspect of lynx biology and management to date involves consideration of the contribution of habitat factors to population levels. Precise habitat protection requirements and enhancement possibilities for lynx are not yet known, but it is clear that the largest potential for habitat-related impacts on lynx in B.C. is in the forest industry, whose activities are dominant and widespread throughout the province. Population management objectives cannot be met without a suitable interspersion of a) "mature" forest for cover and denning, and b) earlier seral habitats that support snowshoe hares and thereby provide the nutritional basis for lynx population growth and expansion. Forestry matters that need to be addressed in relation to lynx management include, but may not be limited to, the following:

- Fire suppression, as it may limit production of new hare habitats.
- The compatibility, by vegetation zone or region, of hare habitat enhancement and forestry/silviculture objectives.
- Cutblock size and juxtaposition with adjacent habitats.
- Silvicultural treatments that may affect hare production.

RESEARCH NEEDS

Additional information on population dynamics is needed, but ongoing research in Alaska and the Yukon may suffice. The most pressing information needs in British Columbia are for a better understanding of snowshoe hare distribution, biology, and cycle patterns in the diverse ecological zones of the province, and of habitat requirements and relationships for both hares and lynx in those areas.

Data on the nature and extent of lynx occurrence in particular areas of the province, i.e., whether due mostly to immigration or local reproduction, may be determinable from harvest samples, but separate research will be required for aspects of hare biology and lynx habitat use.

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PART 2: THE BIOLOGY AND MANAGEMENT OF LYNX

2.1 INTRODUCTION

This section is to provide documentation for the contents of Part 1 (Lynx Management Strategy For British Columbia), in the form of a topical summary of the biological and social factors that seem most clearly to relate to that subject. It is primarily a literature review, based on the 151 references listed and described in Part 3, but it also includes my interpretation of comments and concepts that emerged during telephone conversations with selected (key) managers and researchers in western North America, and during less formal conversations with a few British Columbia trappers.

The operative term, here, is MANAGEMENT--the collective actions both by trappers and by professional wildlife and habitat managers, to sustain and/or enhance populations of the species. Other recent reviews, e.g. McCord and Cardoza (1982) and Tumlison (1987), have provided detailed coverage of lynx biology, therefore a similarly directed effort is not presently required. The general approach in this review is to proceed systematically through a list of subject headings and keywords generated in the bibliography (Part 3), and to briefly discuss each in terms of its known or potential relevance to management. To provide an overall perspective, initial sections characterize the body of literature consulted and describe the history and status of lynx management and research in British Columbia.

2.1.1 Characteristics of Literature on Lynx

The subject index lists the frequency of occurrence of various subject headings and keywords used to describe and categorize the references identified in the bibliography section (Part 3). Compilation of those frequency data enables the following generalizations about the body of lynx literature assembled:

Geography - About a quarter of the 151 references related to general locations including the species entire Holarctic distribution (3.3%), North America (8.6%), or Canada (13.9%). Within Canada, the provinces and territories that were the subject area for the most papers were Alberta (8.8%), Newfoundland (6.0%), British Columbia (5.3%), Ontario (4.6%), and the Northwest Territories (4.0%). The other five Canadian jurisdictions listed were each featured in less than 3% of the assembled papers. The most frequent specific source location was Alaska (11.9%), while only one other state Minnesota (3.3%) appeared in 3% or more of the papers. A total of 14 papers (9.3%) were set in Eurasia, especially the Scandinavian countries.

Methods - Among 133 papers for which methods could be tabulated, most (42.9%) were essentially desktop projects. The present document is yet another of what proved to be the most common category--review and synthesis of existing data and literature (30.1%). Of the other cerebrum-to-paper projects, the most common were academic considerations, mostly mathematical, of population cycles (9.0%), followed by population modelling (2.3%), bibliography (1.5%), and presentation of trapper interview results (0.8%). Indoor projects of a more truly biological nature (21.8%) included post-mortem examination of harvest samples and other specimens (12.0%), and food habits analyses (3.8%). Although over a third of the papers reported results from outdoors

(34.6%), many of those were based on one-time incidental observations (10.5%). Methods used in actual field studies included telemetry (10.5%), snow-tracking (5.3%), and combinations of those and other methods (5.3%).

Management Significance - Of 133 papers subjectively rated as nil, low, medium, or high in terms of their perceived significance to management, 32 (24.1%) were judged high and 36 (27.1%) were considered medium. Within the high category, published field studies that managers should be particularly aware of include the pioneering work in Alberta (Nellis and Keith 1968; Nellis *et al.* 1972; Brand *et al.* 1976), and reports on more recent projects in Nova Scotia (Parker 1981; Parker *et al.* 1983), the Yukon (Ward 1985; Ward and Krebs 1985), and Alaska (Bailey *et al.* 1986). Also included in the high category are preliminary reports from recently completed or ongoing field projects in Alaska (Stephenson 1984c, 1986; Bailey *et al.* 1987), Washington State (Brittell 1987; Koehler 1987b), and the Yukon (Ward and Slough 1987). Laboratory studies of note include analyses of harvest samples and data from Alberta (Brand and Keith 1979), Nova Scotia (Parker *et al.* 1983), Alaska (O'Connor 1984), and Ontario (Quinn and Gardner 1984; Quinn and Thompson 1985, 1987). The most detailed discussions of current management problems and options have been provided by Todd (1985) and ADFG (1987).

Topics - Among 133 indexed papers, the most frequently occurring subject headings were population dynamics (54%), life history (50%), and species management (42%). Aspects of population trends and/or cycles were the most common category under population dynamics (about 32%), while food habits (20%) and dispersal (14%) were common topics under life history. Most of the papers under species management referred to some aspect of the harvest (29%). Habitat characteristics and management were the least addressed topics, with only 6% of the papers describing specific cover types and only 2% offering or implying habitat management recommendations.

2.1.2 Lynx Management/Research In British Columbia: A Review

Only eight of the references located (5.3%) featured British Columbia as the primary geographical location. I was not able to locate a copy of the earliest of those (Brooks 1909), but it is evident that it did not report on original field research. An important question for lynx occurrence in B.C. is whether the populations are cyclic in numbers, as in areas farther north. In a general discussion of the phenomenon in Canada, Hickey (1954) was aware of "no satisfactory evidence" for lynx cycles in the Maritimes or in British Columbia. However, Cowan (1938) had shown that they do occur in B.C., with pelt sales peaking in 1828, 1836, 1846, and 1855. He noted that at New Caledonia, in the north-central portion of the province, annual production of lynx pelts ranged from 49 to 4246 during the historic period examined. More recently, Spalding (1971) described some "...very abrupt and short-lived" increases in pelt sales in B.C., from an annual average of about 2000+ to 8000+ in 1924 and 12 000+ in 1962. A more detailed discussion of B.C. harvest patterns is presented later, but the foregoing serves to suggest both that lynx harvests, and probably populations, fluctuate in B.C., and that those fluctuations are of the regular (periodic) variety observed in other areas. The trapper compensation policy of B.C. Hydro (1981) includes formulas for losses of lynx yield at both "low" and "high" population levels, implying that a documented cyclic pattern exists.

Perhaps the only written information on the relative abundance of lynx on the ground in B.C. may have come from impact studies in relation to proposed dams, e.g. Penner (1979). Unfortunately, I was not able to procure any of the relevant reports in the time available here. The only papers that might be construed as dealing with the biology of lynx in B.C. are those by Adams (1966), describing a parasite from a specimen taken in an unspecified location, and Wilson (1969), documenting an apparent case of lynx predation on a marmot or woodchuck in the Babine Lake area. I am aware of no specific field or laboratory research on any aspect of lynx life history or population dynamics in British Columbia.

Among the B.C. literature available, the premier document is probably that of Goodchild and Munro (1981) in that, through its statements on the most recent provincial management policy and objectives for the species, it establishes the context for the present project. The guiding policy is that lynx "...will be managed primarily for commercial use as (a) fur-bearing species" and that "Trapping and hunting seasons will be restricted to the period of prime pelts." The stated objectives are to:

1) "Maintain viable...populations throughout...existing ranges."
2) "Develop indices for measuring...population status..."
3) "Provide for a commercial harvest of about 10 percent..."

In addition, two "management prescriptions" are listed:

1) "Maintain the habitat of the major prey species of the lynx..."
2) "Monitor harvests as an index to population status."

2.2 DESCRIPTION

2.2.1 Features

Local differences in form or size might suggest some kind of local biological specialization that should be taken into account in management. Table 2-1 lists some reported weights of animals from different areas. It is apparent that the European lynx is larger than the North American subspecies, and that males are generally larger than females; those patterns are also confirmed by skull measurements (Kurten and Rausch 1959; Wiig and Anderson 1986). However, until someone conducts a statistical comparison involving a variety of body measurements on suitable series of age-specific specimens, it will not be clear whether there is any geographical variation in size on this continent. Werdelin (1981) concluded that there had been little change within the North American lynx in its 200 000-year history. If true, that may be a result of the regular, large scale dispersals that are believed to occur, resulting in little opportunity for local segregation of gene pools (see Butler 1953). There is some justification, therefore, for assuming that lynx study results from other areas are applicable to management deliberations in British Columbia.

Table 2-1. Some weights of lynx (kg) in Eurasia and at scattered locations in North America

Location	Male			Female			Source[1]
	N	Mean	Range	N	Mean	Range	
EURASIA							
Sweden	13	17.9	-24.0	10	16.8	-22.0	1
USSR	1?	-	-32.0	1?	-	-38.0	2
NORTH AMERICA							
British Columbia[2]	3	8.2	?	4	8.2	?	3
Northcentral B.C.	3	10.8	10.4-11.0	3	8.8	8.2- 9.5	4
Washington	5	11.3	10.4-11.8	2	8.2	7.7- 8.6	5
Alaska[3]	6	10.6	8.4-12.0	8	8.6	7.0- 9.8	6
Newfoundland	93	10.7	6.4-17.2	91	8.6	5.0-11.8	7
Nova Scotia[4]	?	9.9	4.6-12.7	?	8.8	4.1-10.0	8
Manitoba	1	15.0	-	2	12.3	10.9-13.6	9
Oregon	-	-	-	1	14.5	-	10
Wisconsin	-	-	-	1	8.6	-	11
Michigan	1	11.8	-	-	-	-	12

[1] Sources - From Bibliography (Part 3): 1 - Haglund 1966, 2 - Tumlison 1987, 5 - Koehler 1987b, 6 - Stephenson 1986, 7 - Saunders 1964, 8 - Parker *et al.* 1983, 9 - Carbyn and Patriquin 1983, 10 - Coggins 1969, 11 - Doll *et al.* 1957, 12 - Erickson 1955; Other Sources: 3 - Cowan, I.McT., and C.J. Guiguet. 1965. The mammals of British Columbia. B.C. Prov. Museum Handbook No. 11, Victoria. 414pp. 4 - D. Hatler, unpublished data, Bulkley Valley area, B.C.

[2] Locations and specimen ages not given.

[3] Includes 2 weights for one individual male and 3 for one female--captures separated by 9 months or more.

[4] Weights as extrapolated from the authors' Fig. 4 for skinned carcasses, and with their suggested 10% added to approximate whole weights; all specimens aged at 2+ years.

2.2.2 Taxonomy

Formerly considered to be separate, the Palearctic and Nearctic lynx are now lumped into one circumpolar species, *Felis lynx* (McCord and Cardoza 1982). The Newfoundland lynx has been considered a separate subspecies, and is still listed as such (Tumlison 1987), but Van Zyll De Jong (1975) found insufficient differences to justify that separation. Thus, consistent with the above conclusions relating to physical features, the North American lynx is probably monotypic, all referable to the subspecies *F. l. canadensis*. Although the lynx is related to the bobcat (*F. rufus*) as closely as the subgenus level (Tumlison 1987), the two are believed to have arisen from different Eurasian ancestors, the bobcat arriving on this continent much earlier (Werdelin 1981). Thus, although there may be a temptation to consider management of lynx and bobcats together in areas of sympatry, e.g., in British Columbia (Goodchild and Munro 1980), it should be remembered that the North American lynx is closer in morphology, genetics, habitat requirements, and behavior to the European lynx than to its continental relative (Kurten and Rausch 1959; McCord and Cardoza 1982).

2.2.3 Distribution

The range of the lynx in North America is essentially the northern coniferous forest, which extends across the continent, although the species is generally regarded as absent from the wet forests west of the Coast Mountains in the Pacific Northwest (Shelford and Olson 1935; Tumlison 1987). Many of the papers indexed in the bibliography as dealing with distribution are accounts of rare appearances south of the usual range, e.g., Erickson (1955) in Michigan, Doll *et al.* (1957) in Wisconsin, Halloran and Blanchard (1959) in Wyoming, Coggins (1969) in Oregon, and Rasmussen (1969) in Iowa. The overall present range is smaller than in pristine times, with the animals no longer occurring or greatly restricted in the much cleared and heavily populated eastern United States and adjacent Canada, including the Maritimes (De Vos and Matel 1952; Cowan 1971; McCord and Cardoza 1982). However, there is some uncertainty as to what extent the supposed pristine range involved periodic build-ups of dispersing animals rather than continuous resident populations. Van Zyll De Jong (1971) notes that the range of lynx still expands temporarily "during years of abundance", and he suggests that the "true range" should be considered as the area occupied during both high and low population levels.

2.3 HABITAT CHARACTERISTICS

Most habitat designations in the lynx literature are actually either detailed descriptions of study areas, many of which were selected for logistical reasons as much as for their suitability as lynx habitat (see discussion in Ward 1985), or are classifications of the broad vegetation types in which the study areas were located. Although such descriptions are important, potentially providing useful generalizations when more comparative data on life history and population dynamics become available, I have not found any use for them in the present context--i.e., consideration of lynx management in British Columbia, and will limit further treatment here to the other two categories under the "habitat" heading.

2.3.1 Cover

Within its broad range of coniferous forest habitats, the lynx is known to use both climax and early seral stages. Given the dominant role of the forest industry in both the economy and ecology of British Columbia, knowledge of the specific forest requirements of lynx is of critical importance for effective management. The nature and duration of lynx activities within different aged stands and various, local patches of disclimax cover have been monitored in a few instances by telemetry and/or by snow-tracking, with the following results:

- **USSR**, study effort difficult to decipher, but involving hundreds of km of snow-tracking in 1949 and 1950, following similar work of lesser intensity in the early 1930's (Iurgenson 1955):
  In general, lynx "traveled" (hunted) in areas where hares were most abundant, and the distribution of hares varied in the years studied. The 1930's data are summarized as showing that the most used habitats were "...old, full-grown plantings with windfall and undergrowth, borders of swamps, overgrown thickets of birch grove, willow, and burns which are becoming overgrown", while habitats the animal appeared to avoid included roads and wet areas such as bogs. In January 1950, based on 450 km of tracking, the most used habitats appeared to be older forest types, both spruce-dominated and those containing significant amounts of deciduous trees, although 17 of 25 types listed were used, and use may have been in proportion to the abundance of each type rather than a reflection of preference. Denning habitat was described as "Thick, remote portions of old spruce forest with an abundance of windfall...", often as "islands" in bogs.

- **Northcentral Washington (bordering B.C.)**, telemetry and snow- tracking coupled with detailed descriptions of habitat utilizing LANDSAT technology, 1984-87 (Koehler 1987b):

  Based on the incidence of cover types within the home ranges of 7 radio-collared animals, preliminary conclusions are that "...lynx select for areas dominated by lodgepole pine and spruce-subalpine fir forests and avoid xeric forest types and open meadows." Snow-tracking suggested that the pine types, including both young post- fire (57 years) and post-logging (37 years) regeneration , were used primarily for hunting, since snowshoe hares used those types extensively. All of 4 natal dens were located in mature spruce-subalpine fir forests on N-NE aspects, and featuring numbers of downed trees.

- **Northwestern Montana**, telemetry locations for a female in January and a male in March-October 1977 (Koehler *et al.* 1979):

  Of 29 radio-locations for the two animals, 26 (90%) were in a 67 year-old burn, and most of those were thickly stocked with lodgepole pine and supported a good population of snowshoe hares; the other three locations were in an adjacent, mature Douglas fir- larch stand.

- **Cape Breton Island (Nova Scotia)**, snow-tracking along 192 km of lynx trails during January-April 1978, and cover type descriptions and quantification from aerial photos (Parker 1981):

> Lynx were highly selective in their use of habitats, conducting most of their travel and hunting activity in advanced successional (22-28 years) and open mature conifer types. The advanced successional type was characterized as the "optimal winter snowshoe hare habitat"--younger successional types (14 years) were less important to hares (and therefore to lynx) in winter because of the lack of conifer cover. Mature deciduous forest types were little used, while "...open spruce-dominated bogs were often used for resting and socializing."

In a recent review of lynx management needs and options in Alaska (ADFG 1987), it was concluded that the two broad habitats of greatest importance to lynx are 1) "mid-successional vegetation stages" produced by fire within large expanses of mixed forest, and 2) alpine shrub thickets, which apparently serve as food refuges for lynx during lows in the hare cycle in adjacent habitats. The importance of those habitats relate to the lynx's food requirements, but it is clear from the studies described above that more mature habitats are also used, and possibly required, for other activities. As noted by Shelford and Olson (1935), "It can be said...that though the lynx may live and die in the climax, it depends upon the subclimax for its food."

2.3.2 Climate

Climate is a conspicuous feature of habitat in its influential role on vegetation characteristics, but weather factors may also act directly on the animals and may influence our view of population status through effects on trapper success or census opportunity. Some students have looked for cyclic weather patterns to explain the incidence and extent of cycles in some northern animals, including the lynx. Arditi (1979) suggested that "unusual" precipitation and temperature patterns in the seasonal transition periods (spring-summer and fall-winter) influences juvenile hare survival. Fox (1978) correlated the extent and periodicity of hare/lynx cycles to the extent and frequency of fires. Although suggesting that fire was the primary controlling variable, he postulated that precipitation (primarily characteristics of winter snow as it might affect access of hares to their food supply) tended to modify the response of hares to the abundance of post-fire successional habitats. Wing *et al.* (1985) also considered snow a potentially important factor in the hare cycle, showing a 10-year cycle in "moderate snowfall" and noting that "snowfall increases the quantity/quality of vegetation at times of low hare density, and moderate snowfall also provides cover and warmth while permitting browsing."

There is some evidence that snow density and hardness characteristics may affect the access of lynx to food, with reduced hunting success under soft footing conditions (Nellis and Keith 1968; Parker 1981). Hunting success may also be affected by the degree to which hare activity is confined to well- defined trails in the snow. The lynx is well-adapted to cold, deep snow conditions (McCord and Cardoza 1982), but its mobility may nevertheless be greatly impeded in some snow conditions (Iurgenson 1955).

It is acknowledged that weather conditions are not directly subject to management, but for management to be either responsive or predictive, there is a need to understand the role of such factors on the population dynamics and/or harvest vulnerability of the species.

2.4 LIFE HISTORY

The distinction between life history and population dynamics in this review is not a sharp one. The general intent is to separate out, in the life history category, those aspects of biology that can be thought of in terms of the single animal or, as in the case of food habits, the input from series of single animals. Population dynamics topics, on the other hand, are those directly relating to numbers of animals. All life history topics discussed below are perceived to have management implications, i.e., can affect populations, although their effects are usually a step or more removed. Social behavior may be more directly related to abundance than many of the other topics listed, but it is nevertheless included under life history because it is expressed at the individual level. Mortality and natality both act at the individual level, and therefore could be considered under life history by the above criteria, although their role in population dynamics is obvious enough to include them there.

2.4.1 Food

Table 2-2 summarizes the major foods of the North American lynx at several locations within its range. As emphasized in all reviews of lynx biology, the high degree of the animal's reliance on a single prey species, the snowshoe hare, is at once apparent. All sample series in all studies found the hare to be the No. 1 ranking prey, even during lows in the hare cycle, with frequencies of occurrence ranging from 35-97% and estimated percentage volume (or biomass) ranging from 41-100%. Other commonly used prey include red squirrels, mice and voles (especially *Microtus* and *Clethrionomys*), and various birds (especially grouse). Ungulates were also used, both as carrion and as direct prey; during hare lows, lynx have been demonstrably serious predators on caribou calves in Newfoundland (Bergerud 1971; Lien and Mercer 1980), and they have also been documented as killing caribou (both young and adults), red foxes, and a Dall's sheep in Alaska (Stephenson 1986).

At least some European lynx have been known to prey heavily on hares, e.g. those in southeastern Finland (Pulliainen 1981) and in the taiga of central USSR (Iurgenson 1955). However, the larger European animal also appears to use ungulates frequently, especially roe deer and the young of red deer (Iurgenson 1955; Haglund 1966; Cop 1977).

The only specific record of lynx food in British Columbia is that by Wilson (1969), documenting remains of a marmot (presumed but not demonstrated to be *Marmota monax*) in a stomach. It is common knowledge among B.C. trappers, however, that lynx frequent areas of hare abundance, and the relationship between the two species is probably similar to that described elsewhere. The predominance of hares in the diet of the North American lynx (Table 2-2), and the apparent relationship between hare abundance and lynx abundance (Keith *et al.* 1977, and others), suggest that a management strategy for lynx must at least consider the biological needs and/or status of hares. Unfortunately, however, that consideration can not be given here. Appendix A provides a selected list of references on snowshoe hare biology, to at least give the interested reader a place to begin.

Table 2-2. Major foods of lynx in North America, as recorded in the literature

		Rank and % Occurrence of Prey Items (Sp.[1])									
		No. 1			No. 2			No. 3			
Location	Samp.[2]	Sp.	Freq.	Vol.	Sp.	Freq.	Vol.	Sp.	Freq.	Vol.	Lit[3]
Alberta	D-3-W-H	SH	90	97	MV	4	<1	BD	3	3	1
	D-4-W-L	SH	66	86	SQ	9	3	MV	7	<1	1
	D-4-W-L	SH	35	65	MV	28	1	SQ	12	3	1
	S-?-W-H	SH	-	99	MV	-	<1	OT	-	<1	2
	S-?-W-L	SH	-	95	OT	-	2	CA	-	2	2
	S-?-W-L	SH	-	97	CA	-	3	MV	-	<1	2
	S-?-W-L	SH	-	94	GR	-	4	SQ	-	2	2
	S-?-S-L	SH	-	91	OT	-	4	CA	-	3	2
	T-?-W-H	SH	-	100	OT	-	<1	-	-	-	2
	T-?-W-L	SH	-	90	CA	-	5	GR	-	4	2
	T-?-W-L	SH	-	96	GR	-	3	SQ	-	1	2
	T-?-W-L	SH	-	81	GR	-	12	SQ	-	6	2
	T-1-W-L	SH	-	69	GR	-	13	SQ	-	1	3
	M-4-W-L	SH	-	76	CA	-	10	GR	-	9	4
Alberta/NWT	D-1-S-?	SH	52	-	MV	31	-	SQ	9	-	5
	D-3-W-?	SH	79	-	MV	10	-	UG	6	-	5
NWT	S-1-W-L	SH	83	-	SQ	56	-	GR	17	-	6
Nova Scotia	D-3-W-L	SH	97	-	UN	5	-	GR/MV	3/3	-	7
	S-3-W-L	SH	93	-	MV	7	-	UN	5	-	7
	S-4-S-L	SH	70	-	UG	9	-	BD	6	-	7
Newfoundland	M-4-S-U	SH	67	-	BD	33	-	MV	19	-	8
	M-4-W-U	SH	73	-	BD	21	-	CA	-	15	8
	D-1-S-U	SH	-	41	CA	-	33	BD	-	5	8
	D-1-W-U	SH	-	71	MV	-	9	CA/BD	-	5/5	8
Alaska	D-3-W-L	SH	68	-	MV	14	-	BD	9	-	9
	S-2-N-L	SH	87	-	SQ	13	-	BV	3	-	9
Washington	S-2-N-U	SH	79	-	SQ	24	-	UN	2	-	10

[1] Sp. (Prey species and/or groups) - BD = Unspecified birds, BV = beaver, CA = Carrion, GR = Grouse, MV = Mice and/or Voles (Cricetidae), OT = "Other" (Other than the items mentioned), SH = Snowshoe Hare, SQ = Red or Flying Squirrel, UN = Ungulate (other than obvious carrion).

[2] Samp. (Characteristics of the sample) - 4 digits representing: Type (S = scats, D = digestive tracts, T = results from tracking, M = More than one type); Sample Size (1 = 1-25, 2 = 26-50, 3 = 51-100, 4 = 101+); Season (W = winter--November-April, S = "summer"--May-October, N = seasons not specified or distinguished); Stage of Hare Cycle (H = High, L = Low, U = Unspecified).

[3] Lit (Literature Source): 1) Brand and Keith 1979, 2) Brand *et al.* 1979, 3) Nellis and Keith 1968, 4) Nellis *et al.* 1972, 5) Van Zyll De Jong 1966a, 6) More 1976, 7) Parker *et al.* 1983, 8) Saunders 1963a, 9) Stephenson 1986, 10) Koehler 1987b.

2.4.2 Nutrition

There have apparently been no formal, physiological studies of lynx energetics. Based on the observed food consumption of two captive animals, and on kill rates determined during snow-tracking studies in Newfoundland, Saunders (1963a) concluded that lynx required, and generally procured, an average of about one/half hare (or an equivalent biomass of other prey) per day. Brand *et al.* (1976) calculated similar prey consumption (0.4-0.5 hare equivalents per day) when hares were low on their Alberta study area, but consumption was 37% higher (0.7-0.8 h.e./day) when hares were abundant. Although nutritional requirements were not known, it was concluded that the lower values may not have been sufficient to maintain free-ranging lynx in good condition, resulting in starvation-related losses of kittens and predisposition of adults to losses by trapping and encounters with humans in settled areas. On Cape Breton Island, Nova Scotia, individual lynx were believed to be consuming approximately one hare per day (Parker 1981), although nutrition-related trapping vulnerability of particular sex and age classes and declines in productivity were documented (Parker *et al.* 1983).

Thus, although the actual values relating to food consumption and metabolism may of only academic interest, the level of nutrition is of management interest in its relationship to both the productivity and security of lynx populations.

2.4.3 Activity

Based on aspects of temporal harvest composition in Ontario, Quinn and Thompson (1985) postulated that yearling males might be subject to increased restlessness, translating to activity, during the onset of the breeding season in late February. There are no data on the subject, however, because all direct studies of activity have focussed on diel rather than seasonal patterns. Snow-tracking studies in Alberta indicated that lynx were active primarily at night, and that they spent most of their activity periods hunting for prey (Brand *et al.* 1976). Saunders (1963b) and Haglund (1966) confirmed the general nocturnal pattern for lynx in Newfoundland and Sweden, respectively, and both also noted that animals reduced or ceased activity during bad weather. Three radio-collared lynx in Alaska (1 male, 2 females) spent a combined total of 65% hunting and 35% resting during a low in the hare cycle (Stephenson 1986), but it is likely that those numbers would change with hare abundance and/or other factors influencing hunting success. Parker *et al.* (1983) found some radio-collared lynx inactive in early evening, an uncharacteristic pattern, and assumed that they had made a kill early; others that remained active all night were presumed to have been unsuccessful.

Thus, it appears that, like productivity and trapping vulnerability, changes in the extent of individual activity may be inversely related to nutrition. However, there may be no practical use, in management, for knowledge about activity, unless monitoring activity patterns of selected individuals could provide an index to the state of lynx response to local hare population levels and trends.

2.4.4 Movements and Dispersal

The term "movements" includes dispersal in its generic meaning; however, it is used here primarily in reference to short-term activity within well- defined ranges, while dispersal includes major, long

distance and often longer term phenomena (e.g., emigration and immigration) that take individuals to new ranges. The former category of movements seems the less important in the context of management, and will be dispensed with first.

Movements - As described under activity (2.4.3), most daily movements are directed to hunting, and the extent of movements would be expected to vary with prey density and/or hunting success. Based on snow-tracking, average daily cruising distances for lynx were about 8 km in Newfoundland (Saunders 1963b) and Nova Scotia (Parker 1981), and in the Rochester area, Alberta, ranged from 3.3-8.0 km in different years (Brand *et al.* 1976). In the Alberta studies, distance traveled was related to hunting success, but neither kill success or distance traveled were directly related to hare density. Nellis and Keith (1968) found that daily movements increased and hunting success decreased between years, despite increases in hare density. They speculated that the observed pattern was due primarily to differences in snow characteristics (higher bearing strength enabling better footing and therefore better success in the first year).

Telemetry results are similar to those obtained by snow-tracking, with average daily cruising distances for three lynx in Nova Scotia ranging from about 8 km in winter to about 9 km in summer; the adult female moved an average 1-2 km more each day than the male which, in turn, moved 1-2 km more than the juvenile female (Parker *et al.* 1983). In Alaska, Stephenson (1986) recorded distances between daily locations (cruising radii) similar to those found in the above studies, thus actual distances traveled during the animal's meanderings between those two points may have been similar as well. Daily straight-line distances during dispersal movements were comparable, averaging 6.5-8.0 km. The most intensive study of movements to date, that by Ward and Krebs (1985), documented an almost doubling of daily cruising radius figures, from 2.7 to 5.3 km, between periods of high and low hare densities, respectively. Their analysis and discussion indicate that this expected result--increased foraging effort with decreased prey abundance--was not documented in previous studies because hare densities had not reached sufficiently low densities in the other studies.

Clearly, movements are closely related to both activity and home range, and are of interest to managers for the same reasons. That is, animals that are nutritionally stressed or otherwise insecure will probably be more active, moving more and having larger ranges, and they are therefore more likely to encounter and fall victim to trap sets and/or to appear in settled areas.

Dispersal - In consideration of lynx management, dispersal may be one of the most important topics. There is evidence, particularly along the southern edge of the North American range, that it may occur *en masse* following hare declines farther north (Adams 1962; Mech 1973, 1980; Gunderson 1978). Further, it has been postulated that observed temporal harvest patterns across the continent, and the bulk of some local populations and harvests, arise largely through dispersal from other areas (Butler 1953; Lack 1954; Maliepaard 1971). In addition to the "irruptions" and "invasions" described by the above authors, dispersal has also been manifest in rare occurrences outside the usual, continuous geographic range, such as in Michigan (Erickson 1955), Wisconsin (Schorger 1947; Doll *et al.* 1957), Iowa (Rasmussen 1969), and Wyoming (Halloran and Blanchard 1959).

More recently, observations of marked animals have provided some more direct and specific information on the nature and extent of lynx dispersal movements, as follows:

A) 164 km, northwestward within Alberta, 163 days: this adult male, previously resident in the initial capture area, moved after losing a foot in a trapping incident (Nellis and Wetmore 1969).

B) 483 km, from northeastern Minnesota to southeastern Ontario, 3 years: female, believed young when first captured (Mech 1977).

C) 169 km (minimum), eastward and then southwestward within Alaska, then contact lost, about 44 days: adult female, resident in small area for at least 2 months prior to late March departure (Stephenson 1986).

D) 250 km (2 individuals in separate incidents), northeast within the Yukon Territory, 8 months and 1.5 months: (male and female, resident in the initial capture area 40 days and 7 months before dispersal (Ward 1985).

E) 700 km, northwest from southern Yukon to northeastern Alaska, 8 months: adult female, resident in initial trapping area for at least 35 days before commencing dispersal (Ward 1985).

F) 616 km, north from Washington State to Prince George area, B.C., 202 days (between late April and mid-November 1983: adult male, resident in Wash. at least 23 months before dispersal (K. Child, Prince George, and J.D. Brittell, Washington Game Branch, pers. comm.).

G) 210 km (estimate), north from Washington State to Skimikin Lake area, south of Sorrento, B.C., dispersal time not determined: adult male, transient in Washington during its time there--no additional details (R. Ritcey and Brittell, pers. comm.).

It seems noteworthy that although the conspicuous lynx "irruptions" in the northern United States are generally believed to have been due to mass southward movements from Canada (e.g., see Mech 1973, 1980), seven of the eight documented dispersals, above, were to the north. Thus, although local increases due to dispersal are more likely to be noticed in southern areas, where human populations are larger, it would appear direction of movement is neither completely predictable nor fully understood.

As with aspects of movements and home range, the most illuminating data on dispersal have come from the recent Yukon studies (Ward 1985; Ward and Krebs 1985). All three of the dispersals documented in that study (D and E, above) occurred during the rapid decline phase of the hare cycle, and all during the snowfree season. Once hare numbers became stable, though low, other lynx in the study area expanded their home ranges or became nomadic, but none dispersed. Although those results suggest that dispersal is related primarily to prey abundance, it seems likely that some kind of dispersal of juveniles also occurs at times when both hare and lynx numbers are higher than was the case during the above studies. There are as yet no data on that.

Considering lynx harvest records, Spalding (1971) described the peaks in British Columbia as "sudden and short-lived". If accurately reflecting population levels, that pattern may indicate that dispersal is important in the growth of lynx populations in at least some areas of the province. As noted by O'Connor (1984) for interior Alaska, management at the regional level is hampered by lack of knowledge about the role of dispersal in local population processes.

2.4.5 Home Range

Data on home ranges of lynx are difficult to compile and summarize (Table 2-3), and even more so to interpret. The relatively small body of information in the table was obtained with varying study duration and intensity, by different field study and calculation methods in different areas and different seasons, and involved animals of varying age, sex and nutritional status at different stages of the hare and lynx population cycles. In addition, most involved only small samples.
Like activity, home range size is probably of interest to managers only indirectly, in the degree to which it may reflect environmental conditions and/or the relative stability and density of the local population. Large ranges may indicate relative sparsity of resources, usually food, and/or may reflect a relative absence of social interactions because of low density. The data in Table 2-3 serve primarily as an order-of-magnitude preview of values and variations that can be expected.

The most thorough and focussed study of lynx home range has been that recently conducted in the Yukon (Ward 1985; Ward and Krebs 1985). That study has demonstrated increased home range size with decreasing hare density and, perhaps most importantly in the context of management, has documented abandonment of home ranges in favor of dispersal or nomadism below certain levels of hare abundance. As discussed in the previous section, under dispersal, such animals often end up in the trapper's bag. It is important to know the "normal" fate of animals that abandon their home ranges, in the absence of human factors, and that is one of the questions currently being addressed in a long-term telemetry study of lynx in the Yukon (R. Ward, pers. comm.; Ward and Slough 1987).

2.4.6 Health

The parasitological literature was searched by title and not by index, therefore broad surveys that included lynx only as one of several species examined or as one of several hosts of a particular parasite will have been missed. As recorded in the literature specific to lynx (Part 3), a number of gastro-intestinal parasites, at least one lungworm, and one flea have been recovered from lynx specimens (Table 2-4). In addition, Van Zyll De Jong (1966b) listed seven other species of fleas and one louse that have been reported from lynx. He notes that all but one of the fleas (*Arctopsylla setosa*) are normally found on rodents and lagomorphs and may be only accidental on lynx, and the louse (*Felicola spenceri*) was described as a new species from a specimen found on a British Columbia lynx (no details). As listed in Table 2-4, the only other incidence of parasites among B.C. specimens were some taenids, also common in other areas, mentioned by Adams (1966).

The two most thorough surveys of lynx parasites appear to be those of Van Zyll De Jong (1966b) for a series of 113 specimens from Alberta and adjacent areas of the Northwest Territories, and Smith *et al.* 1986 for 371 Ontario specimens (both during high population levels). All but three of the Alberta specimens (97%) harbored at least one endoparasite species; comparable information

Table 2-3. Home range sizes of adult lynx in North America, as listed in the literature

Study Method	Cycle[1]		Sample[2]			Home Range Sizes[3]					
Location	HA	LY	N	T	DTA	S	Male	Female	Both	Range	Lit.[11]
Snow-tracking											
Alberta	L	L	1[4]	B	230	W	34			19- 50	1
	L	L	3	A	253	W			28	11- 49	1
H	H		2[5]	A	120	W		18		12- 23	1
	H	H	1	A	53	W			37	-	1
Newfoundland	U	U	1[5]	B	39	W		16		-	2
	U	U	2	B	103	W	20			18- 21	2
Radio-tracking											
Alaska	H	L	2	U	U	U		70		51- 99	3
	H	L	1	C	U[6]	Y	783			-	3
	H	L	1	B	U[6]	U	64			-	3
Alaska	L	L	1	B	U	W	54			-	4
	L	L	3	D	250	Y	142			70-210	4
	L	L	3	C	193	Y		75		47-114	4
Minnesota	H	H	2	C	U[7]	Y	194			145-243	5
	H	H	2	C	U[7]	Y		87		51-122	5
Montana	H	U	1	C	29	Y	36			-	6
Washington	U	U	?	U	U	Y			63	10-111[8]	7
	U	U	2	D	149	Y		41		39- 44	8
	U	U	5	D	210	Y	68			32-102	8
Manitoba	H	H	2[5]	B	36	W		158		138-177	9
	H	H	1	C	49	Y	221			-	9
Nova Scotia	L?	L	1	D	U	Y		32+		W19-S32[9]	10
	L?	L	1	D	U	Y	26+			W12-S26[9]	10
Yukon[10]	H	U	4	B	240	Y			30	12- 46	11
	M	U	5	B	263	Y			44	17-104	11
	L	U	5	B	482	Y			70	34-114	11

[1] Cycle - Level of (HA) and lynx (LY) population: H=high, L=low, U=unspecified.

[2] Sample Characteristics - N=Number of animals; T=tracking period (A=1-30 days, B=31-180 days, C=181-365 days, D=366+ days, U=unspecified); DTA=Data Points (For snow-tracking, total km of lynx trails; for telemetry, number of locations; U=unspecified); S=Season (W=winter, Nov.-April; S=summer, May-Oct.; Y=data from both seasons, or year-round; U=unspecified).

[3] Homes ranges (km^2), rounded to nearest whole number.

[4] Same individual, tracked in 2 different years; home range figure is mean.

[5] Females accompanied by kittens.

[6] Radio-tracking frequency given as 1-10 times per month.

[7] Home ranges based on minimum of 18 locations for each animal.

[8] By sex, males 21-111 and females 10-111 km^2.

[9] Summer (S) and winter (W) ranges for the same individual.

[10] Home ranges calculated separately in 3-month blocks for each individual; H, M, and L under Cycle (HA) refers to measured hare densities of 14.7, 1.0-3.3, and <1.0 hares/ha, respectively.

[11] Literature Sources: 1) Brand *et al.* 1976; 2) Saunders 1963b; 3) Bailey *et al.* 1986; 4) Stephenson 1986*; 5) Mech 1980; 6) Koehler *et al.* 1979; 7) Brittell 1987*; 8) Koehler 1987b*; 9) Carbyn and Patriquin 1983; 10) Parker *et al.* 1983; 11) Ward and Krebs 1985; those marked with an asterisk are preliminary and/or unpublished reports.

Table 2-4. Some parasites of lynx in North America, as recorded in the literature

Parasites[1]	Incidence[2] of Parasites, By Location[3]				
	B.C.	Alta.	Ont.	Newf.	Other
NEMATODA					
Troglostrongylus sp.					L-1-5-3[4]
Troglostrongylus wilsoni			L-5-5-8	L-5-4-7	
Cylicospirura felineus		S-4-3-5	S-5-5-7		
Cylicospirura subaequalis		S-5-3-8			
Toxascaris leonina		I-5-5-8	G-5-5-7		
Toxocara cati		I-5-1-8	G-5-2-7		
Capillaria aerophila			T-5-1-7		
Physaloptera rara			S-5-1-7		
Physaloptera praeputialis		S-5-1-8			
Ancylostoma caninum			I-5-1-7		
Uncinaria stenocephala			I-5-1-7		
CESTODA					
Taenia rileyi	U-U-U-1	I-5-4-8	I-5-3-7		I-1-5-4[5]
Taenia laticollis	U-U-U-1	I-5-5-8	I-5-5-7		
Taenia macrocystis				I-3-5-2	
Taenia pisiformis		I-5-3-8	I-5-1-7		
Taenia serialis			I-5-1-7		
Multiceps sp.		I-5-2-8			
TREMATODA					
Alaria marcianae			I-5-1-7		
Alaria sp.		I-5-1-8			
ACANTHOCEPHALA					
Oncicola canis					U-1-5-6[6]
ECTOPARASITES					
Monopsyllus vison		E-3-2-8			

[1] Parasite names as presented by the authors indicated.

[2] Incidence of parasites - 4 letter/number codes, as follows:
First - Organ infected (S=stomach, I=intestine, G=both stomach and intestine, T=trachea, L=lungs, E=external, U=unspecified).
Second - Number of lynx specimens (1=1, 2=2-10, 3=11-25, 4=26-50, 5=51+, U=unspecified).
Third - Infection rates (frequency) - 1=<5%, 2=5-25%, 3=26-50%, 4=51-75%, 5=76-100%, U=unspecified).
Fourth - Literature Source: 1) Adams 1966, 2) Bursey and Burt 1970, 3) Kumar *et al.* 1975, 4) Loewen 1929, 5) Pence *et al.* 1978, 6) Schmidt 1968, 7) Smith *et al.* 1986, 8) Van Zyll De Jong 1966b.

[3] Locations: British Columbia, Alberta (including specimens from the Northwest Territories), Ontario, Newfoundland, and "other".

[4,5,6] Under "other", unspecified North American location, Minnesota, and Alaska, respectively.

was not provided for the Ontario series, but 97% of 274 gastro- intestinal tracts examined there contained a single species, the nematode *Toxascaris leonina*. Despite such high frequencies for some parasites, neither the above authors or others cited in Table 2-4 reported any significant parasite-related pathology. There was one report of a wild lynx with pneumonia, found in Alberta (Langford 1974), and cases of rabies and feline distemper have been observed (McCord and Cardoza 1982). However, there appear to be no published records of any chronic diseases or disorders that might have implications for lynx populations.

The factor most often cited in relation to the physical condition of individual lynx is nutrition. Based on body fat indices in a large sample (600+) of carcasses from Alberta trappers in the early through mid-1970's, Brand and Keith (1979) found that adults were generally in better condition than yearlings, males were fatter than females, and that the condition of all classes was poorest in late winters of low hare abundance. Fat deposits were also greater for adults than for yearlings among a sample of 154 carcasses from Nova Scotia, but there were no apparent differences in condition between the sexes (Parker *et al.* 1983). Fat reserves and body weights declined on animals taken through early winter, but then increased again in January through February. That unexpected result was speculated to have been due either to increased hunting experience among yearlings as winter progressed or, more likely, greater trapping vulnerability of animals in poor condition in the early months of the season. A decline of carcass weights over the study period coincided with, and was believed related to, a decrease in hare density in the study area. Stephenson (1986) found "some indications of nutritional stress" among lynx trapped during a hare low in interior Alaska, including several animals (especially younger ones) judged to be in poor or emaciated condition. Condition among live animals has been less well documented, but data gathered by Ward (1985) suggested that females declined in condition more quickly than males in response to a hare decline. Some of those captured during the hare low were described as emaciated, and one female mortality was suspected to have been due to starvation.

As reported by Stephenson (1986), some animals are held alive in traps longer than others, with probable varying effects on their apparent condition after death. Thus, comparisons of condition indices for trapped samples should be interpreted conservatively. However, it seems evident that variations in condition do occur, and that the major patterns of those variations are fairly consistent and believable--older, more experienced and secure animals maintaining better condition than newly independent young, probably males doing better than females that have produced and fed young, and all classes doing more poorly with advance of at least some winters and/or with decreasing prey availability. It also seems to be generally agreed that declining condition tends to predispose animals to human-caused mortality, their increased hunting activity and hunger increasing the likelihood that they will contact and be attracted to baited trap sets, or get into trouble in settled areas (Brand *et al.* 1976; Parker *et al.* 1983; Ward 1985; Ward and Krebs 1985).

2.4.7 Pelage

Since lynx are trapped for their fur, the annual moult cycle is an important consideration in management. As described by Saunders (1964), moult to summer pelage among Newfoundland lynx was in progress by April and moult to winter pelage occurred by October. However, based on extensive literature review and interviews with fur graders, Stains (1979) concluded that the average period of pelt primeness for lynx is from about mid-November through February, and with maximum primeness in December and January. He acknowledges that there may be some

variations in that pattern due to factors such as nutrition, weather conditions, and differences in life cycle schedules by latitude. Based on reports from trappers, Slough (1986) suggested that adult males become prime earliest and stay longest, adult females have shorter prime periods, and kittens are prime for the shortest time.

2.4.8 Denning

Evidence from snow-tracking indicates that lynx bed down at suitable sites along the daily hunting trail rather than returning to any particular sites on a regular basis (Iurgenson 1955; Saunders 1963b; Haglund 1966; Van Zyll De Jong 1966b; Nellis and Keith 1968; Brand *et al.* 1976; Parker 1981).

There are relatively few descriptions that would indicate whether lynx select particular habitats or situations for bedding, but those available suggest that some degree of forest cover is usually present, and that weather conditions determine the density of cover selected. Iurgenson's (1955) summary of the situation was that the lynx "...beds in the snow in a relatively open place under a tree..." Saunders (1963b) reported that beds were often located in dense timber where roots or windfall provided additional shelter, and he recorded two instances of animals using caves in rock ledge areas. Parker (1981) noted that beds were in sheltered situations during stormy weather, but "on clear, mild days lynx often rested on south facing sites, either on open slopes or at the base of spruce or fir trees, taking advantage of the solar warmth." Daily bed sites in summer have not been described, but are probably mostly in timber cover selected either for shade or for protection from precipitation. Parker *et al.* (1983) found two radio-collared lynx using conifer habitats more and successional habitats less in summer than in winter (all activities).

A few natal dens have been located by radio-tracking or by accident. Details are as follows:

- **Interior Alaska:** 26 July 1968 - Female with two kittens seen, and investigation located den among "...a tangle of three blow-down black spruce"; no date - apparent den among blowdown spruce; 4 July 1970 - den containing five kittens with eyes half open, in tangle of spruce roots washed up along a creek (Berrie 1974).

- **Washington:** Four natal dens located, all in mature conifer habitats with N-NE aspects and with an abundance of blowdown (Koehler 1987b).

- **Northcentral British Columbia:** Early summer 1981 - A den with at least two and possibly three kittens was located at the edge of a 6-8 year-old clearcut near Houston. Logging debris had been pushed into a windrow along the forest edge, and there was extensive blowdown on top of that. The kittens were first heard beneath the tangle of trees as the observers were crossing it, and one was subsequently retrieved from a moss-floored cavity, and photographed--it was small, "still with blue eyes" and was easily caught. An adult was glimpsed in the woods nearby (W.G. Hazelwood, pers. comm.).

In addition to the above observations, Stephenson (1986) noted that a collared adult female later observed with kittens localized, and probably established a natal den, "...in an area of mixed mature spruce and birch where numerous windfalls were present." Iurgenson (1955) provided no specific details of any one natal den site, but generalized that islands of "...thick, remote portions of old spruce forest with an abundance of windfall" surrounded by bogs were the preferred sites.

The above observations all suggest that old-growth forest is preferred, if not required, for denning, and is therefore an important component of lynx habitat.

2.4.9 Behavior

The primary management-oriented interest under this heading relates to territoriality--individuals attempting to maintain areas of exclusive use--and the question of whether that behavior serves to limit population size. From direct observations of captive animals, Lindemann (1955) described what appears to be a basic tendency to a solitary, home-based territorial system among European lynx. Behavior among kittens during the approximately 10- months duration of the maternal family grouping changes, in the later stages, to "...an ever more pronounced striving to live apart.." with increasing intolerance and prey envy. It was noted that lynx reacted strongly to the smell of lynx feces, and that they marked "territorial boundaries" with both feces and urine. Marking behavior was particularly intensive during the breeding season. Finally, lynx showed "remarkable" orientation and homing abilities, and were "strongly imprinted" to familiar features in their surroundings. That suggests that the primary adaptation is for an existence in a well-defined home range, rather than for extensive wandering.

All other evidence on the social behavior of lynx has been indirect, mostly based on the nature and extent of range overlap observed among marked animals. As with home range, each study situation involves many variables and the presence or absence of territorial behavior may not be the only explanation for observed concurrent spatial patterns among animals from adjacent ranges, particularly within short time periods. Indeed, as noted by Mech (1980), Stephenson (1986) and Ward and Krebs (1985), pairs of animals under observation might be responding to other, unmarked animals more than to each other. Also, behavior between two related animals (mother-progeny, siblings) might be different from that between "strangers".

With those caveats in mind, the local patterns recorded to date have been as follows:

- Little range overlap observed, but some evidence for "mutual avoidance", i.e., animals not occupying the same areas at the same time (Brand *et al.* 1976).

- Slight to considerable range overlap among females, little among males, but overlap between sexes common (Carbyn and Patriquin 1983--data for females only; Mech 1980; Stephenson 1986).

- Little overlap within sexes, but considerable between (Koehler 1987b).

- Considerable overlap within and between sexes (Ward and Krebs 1985).

Mech (1980) recorded several cases of known or suspected concurrent use of overlap areas, especially by females, and Carbyn and Patriquin (1983) documented a case in which an adult female with kittens traveled with two other animals, believed another female and kitten, for at least 30 days. The latter observation was considered to indicate the potential for adoption of orphans in some cases. The most unusual record of social behavior is that by Parker *et al.* (1983), who

reported that a radio-collared adult male "...often met and travelled with the radio-collared female and her three kits."

Both Keith (1974) in Alberta and Brittell (1987) in Washington concluded that lynx have a social organization similar to that of bobcats and cougars, involving social intolerance and mutual avoidance. Continued study has indicated that the pattern on the Washington study area still appears to be like that exhibited by bobcats, i.e., strong territoriality (Koehler 1987b) while, in the Yukon, Ward and Krebs (1985) concluded that "...lynx are not territorial at least during the period of decline of snowshoe hare density. The population implications of the above differences between studies are discussed under "Population Regulation" (Section 2.5.5). Other observed behavior that may have management implications include the following:

Group Hunting - There is evidence that when two or more lynx are traveling together (usually members of a family group), they may "cooperate" in hunting, apparently sharing food that has been captured by diversion tactics (Barash 1971), or by fanning out and increasing the chances of flushing and/or ambushing prey (Saunders 1963a; Haglund 1966; Parker 1981; Parker *et al.* 1983). Strict cooperation seems contrary to Lindemann's (1955) observations of intolerance and prey envy among siblings, and Brand *et al.* (1976) concluded that female lynx fed themselves first and did not always "share" kills with their young. It may be, therefore, that the main benefits of cooperative hunting are training for young animals, and provision of left- overs to non-successful group members (both arguably better than nothing). Parker *et al.* (1983) documented increased hunting success with group size, and attributed it to the cooperative hunting pattern and to increasing hunting skills of young as winter progressed. They suggested that young lynx, orphaned early and forced to hunt alone, may do poorly and become more susceptible to trapping and other sources of mortality.

Adoption - Carbyn and Patriquin (1983) reported that a radio-collared female with two kittens was joined by another female with one kitten, and that the two groups traveled together for 30 days. They suggested that if such incidents were common, it is possible that orphans could be maintained in the more stable family group situation as long as one of the adults remained alive. The relationship of the two adults was not known (possibly siblings or mother-daughter), and no other similar observations have been reported.

Cannibalism - Based on snow-tracking, Elsey (1954) recorded an incident from northern Ontario in which a large lynx (age and sex unknown) pursued, caught, killed, and partially ate one of two "young" lynx (yearlings?) that had been traveling together. This was in late March 1951, at which time data presented by Butler (1953) suggests that hares were in decline in that area. There have been numerous reports of intraspecific killing, including infanticide and cannibalism, among both black and grizzly bears, and bear biologists have perceived some theoretical benefits of such behavior (see reviews under "intraspecific behavior" and "population regulation" *in* Interagency Grizzly Bear Committee. 1987. Grizzly bear compendium. U.S. Fish and Wildl. Serv., Washington, D.C. 540pp.) If a predatory or violent territorial relationship exists between a class of adults and young lynx, as has been described for bears, then there could be population consequences and management implications. However, that probably need not be a concern until there is more evidence on the subject.

Travel Patterns - Some studies have indicated that individual lynx may have particular "favorite" travel routes or "loops" (Iurgenson 1955; Berrie 1974), or at least frequently appear in predictable locations (Brand *et al.* 1976). Berrie (1974) indicated that during a spring observation period, one radio-collared male made four complete circuits, averaging 9.6 days each and that its movements seemed to be determined by topography. Predictability of movements has implications both for trapping and for monitoring of population levels by track counts, but there is no other information on the subject.

2.5 POPULATION DYNAMICS

2.5.1 Cycles

The necessary backdrop for any discussion on lynx population dynamics is consideration of the phenomenon known as the "population cycle", involving numerical increases and declines at regular, predictable intervals. Academics have long been fascinated with the topic as one of the great theoretical puzzles of biology, and the literature is voluminous. Although a complete review is not possible here, a brief account of the evolving discussions and conclusions relating to lynx seems warranted.

Historically, the basic data that attracted biologists and mathematicians were the fur sale records maintained by the Hudson's Bay Company since the early 1900's. Sales for several furbearers showed fluctuations which, though varying in amplitude, were regular in period-- usually approximating either 4 or 10 years. The historic data for lynx emerged as the most consistent, text-book example of the 10-year cycle. Although the lynx fur cycle was referred to by numerous previous authors, including Cowan (1938) for early to mid-nineteenth century British Columbia records, the primary reference on the subject is the synthesis by Elton and Nicholson (1942). Most of the subsequent analyses were directed primarily to explaining the patterns they had described. Included in the early years was a mathematical argument (Cole 1951, 1954) that the 10-year cycle does not really exist. Other observers (e.g., Butler 1953; Rowan 1954), eloquently disagreed, the latter affirming that the problem was a biological, not mathematical one. Perhaps significantly, existence of the cycle with particular reference to lynx data has also confirmed mathematically (Bulmer 1974).

A continuing and legitimate concern throughout the history of thought and argument on population cycles has been the degree to which trends in fur sales have accurately reflected animal population trends, it being understood that other factors such as fur prices, effects of weather or disease on trapping effort, changing priorities among Native trappers as related to food abundance, or even logistical inconsistencies might have been more important (Wing 1953a; Gilpin 1973; Weinstein 1977; Finerty 1979; Winterhalder 1980). Although potentially affecting the amplitude and, to a lesser extent, the timing of peaks, such factors do not explain or refute the periodic (cyclic) nature of the historic harvest data. Further, as acknowledged by Winterhalder (1980), field studies have also demonstrated the reality of cyclic fluctuations in populations of animals, and not just of harvests. That the lynx is cyclic with an approximately 10-year periodicity over much of its range can be considered a given. Two features of lynx cycles that are of major interest in relation to management are 1) their relationship to population cycles of the snowshoe hare, and 2) regional asynchrony. Those features are discussed briefly in following paragraphs.

It has long been understood, at least subjectively, that snowshoe hares exhibit a 10-year cycle, and that lynx population trends closely follow those of the hare (see review in Elton and Nicholson 1942). However, attempts to document and quantify those cyclic phenomena in the field have been relatively recent. Foremost among the field studies of the 10-year cycle have been those in the Rochester, Alberta area by L.B. Keith and his associates. Almost one third of the papers on snowshoe hare biology listed in Appendix A are based on those studies, and Rochester lynx studies have been cited repeatedly in this report (Nellis and Keith 1968; Nellis and Wetmore 1969; Nellis *et al.* 1972; Brand *et al.* 1976; Brand and Keith 1979). As repeatedly indicated by results summarized in the previous (life history) section, lynx are dependent upon snowshoe hares.

Acknowledging the critical dependence of lynx on hares, it seems clear that the question of causes for the cycle is applicable primarily to the hares. The general conclusion, at present, is that the cycle can be explained in terms of "...a hare-vegetation interaction which initiates the (hare) population decline and sets the stage for a predator-hare interaction which extends it" (Keith 1974). The nature of the hare-vegetation interaction is not yet completely clear, and there are a number of applicable hypotheses. Some, such as lunar influences (Archibald 1977) and effects of varying weather patterns (Arditi 1979; Wing *et al.* 1985), are of little more than academic interest since they are beyond management control. Others, such as habitat effects related to wildfire cycles (Fox 1978), are of greater potential management importance, since attempts to manage and control fire is widespread. Regardless of causes, it seems clear that lynx management, like all serious research on lynx in recent years, must consider events and findings in relation to hare population trends.

Although the cycle in lynx pelt production was described mostly on the basis of Canadian totals, Elton and Nicholson (1942) recognized that peaks did not occur in all regions of the country at the same time. Butler (1953) analyzed regional patterns in detail, concluding that peaks begin in the northern prairies and radiate out from there to the west (B.C.) in about 1 year and reaching the east (Ontario, Quebec) in about 2 years. Both he and Lack (1954) suggested that "migration" was the major factor promoting the observed geographical increase pattern. In a more recent analysis, Smith and Davis (1981) found that the "nodal region" has shifted 800 km or more to the east, to northern Saskatchewan and Manitoba. By their reckoning, the cycle in B.C. trails that in provinces from Saskatchewan eastward by 2-4 years, is 1 year behind Alberta, and precedes the Yukon by 1 year. The suggestion that populations in some regions may depend largely on influx from others implies that management of the species may require coordination at a high jurisdictional level, although the fact of regional asynchrony complicates the issue. Further, O'Connor (1984) has shown regional disparity in population changes within a fairly small area of interior Alaska, and possibly a close look would show similar patterns in similar-sized areas in Canadian provinces.

Another difficulty is the tendency for managers and users, in considering cyclic species, to rely on the cycle as the explanation rather than a description of population patterns, and to consider reversals in present trends (ups or downs) as a *fait accompli* that one merely waits for. It can safely be assumed that high populations will decline, but there is no sound basis for faith in the reverse assumption. As described by Elton and Nicholson (1942), an expected cyclic irruption of a Eurasian sandgrouse, despite a long and well-documented history of such events, never recurred. Thus, cyclic populations can be thought of as though acted on by gravity--what goes up must come down, but what comes down only can (not must) go up.

2.5.2 Natality

Reproduction in lynx is known primarily from post-mortem examinations of trapped specimens. Table 2-5 summarizes the results of the major studies to date. By all accounts, the reproductive potential of the species is great, with yearling females capable of producing young and, as listed in Table 2-6, with live litter sizes up to five reported. A consistent and important feature of lynx reproduction is the relationship between productivity and the abundance of snowshoe hares (Table 2-5). All age classes appear to be affected, but the most dramatic reproductive differences between high and low hare population levels occur among yearlings. Based on a large sample of data over one complete hare cycle, O'Connor (1984) projected a 17.3-fold difference in yearling productivity (recent placental scars), as opposed to only a 2.6- fold difference among adults, between high and low hare abundance.

The greatly decreased productivity of yearlings when hares are low parallels decreased measures of condition at that time (Brand and Keith 1979; Parker *et al.* 1983; O'Connor 1984), and is almost certainly related. Poorly nourished young develop more slowly and probably either do not become sexually mature in time for the first breeding season or may fail to produce young because of resulting energetic and/or hormonal imbalances (O'Connor 1984).

Although the data from studies of reproductive tracts indicate a fairly simple and straightforward pattern, related to prey abundance, their interpretation for management purposes is nevertheless not simple. Again as described by O'Connor (1984), the incidence and number of placental scars is not necessarily a measure of recruitment because of *in utero* and early kitten mortality, both of which are believed highest when hares are low. Thus, an apparently productive population as measured by histological parameters may already be declining. She notes that the most accurate measurement of recruitment would be observation of kittens in the field.

Table 2-6 indicates that litters of two to three may appear during the low of the hare cycle, and that litters of four to five have been observed when hares were more abundant. However, probably because the data are scattered in time and space and samples are small, average litter size at three different levels of relative hare abundance varied little from the overall average (2.77 for 26 litters). Although both placental scar counts and maximum litter sizes are highest at high hare levels, and therefore may serve as indicators of productivity, neither can account for losses of young before recruitment. The pattern of winter kitten occurrence on the 130-148 km^2 Rochester study area (Nellis *et al.* 1972; Brand *et al.* 1976) as listed below, is instructive:

Year	Hare Level/Trend	Proportion of Kittens	
		Number	Percent
1964-65	Intermed./decreasing	0 of 11	0
1965-66	Low	0 of 5	0
1966-67	Low	0 of 3	0
1967-68	Intermed./increasing	6 of 9	67
1971-72	High	7 of 13	54
1972-73	Intermed./decreasing	4 of 10	40
1973-74	Low	0 of 5	0
1974-75	Low	0 of 4	0

Table 2-5. Aspects of reproductive performance[1] of North American lynx, as recorded in the literature. The relative abundance of hares is either as stated in or interpreted from the literature sources indicated

	SNOWSHOE HARES ABUNDANT			SNOWSHOE HARES SCARCE			
LOCATION Study Years Age Class	With CL % (N)	With PS % (N)	Mean PS	With CL % (N)	With PS % (N)	Mean PS	LIT[3]
ALBERTA							1
1971-72[2]							
Yearling	61 (143)	40 (129)	3.9	- -	0 (3)	-	
Adult	- -	73 (78)	4.6	- -	33 -	3.4	
NOVA SCOTIA							2
1977-80							
Yearling	- -	67 (6)	3.7	- -	0 (10)	-	
Adult	- -	75 (4)	3.3	- -	64 (14)	3.8	
ONTARIO							3
1979-82							
Yearling	96 (157)	33 (103)	3.9	- -	- -	-	
Adult	99 (111)	85 (72)	4.3	- -	- -	-	
ALASKA							4[4]
1962-72							
Yearling	97 (422)	69 (422)	4.2	19 (27)	7 (27)	3.0	
Adult	99 (232)	76 (232)	4.9	94 (197)	43 (197)	3.6	
ALASKA							5
1982-85							
Yearling	- -	- -	-	0 (11)	- -	-	
Adult	- -	- -	-	58 (19)	42 (19)	3.5	

[1] CL = corpora lutea, the presence of which indicates ovulatory activity and therefore sexual maturity. PS = placental scars; frequency (%) with PS approximates pregnancy rate. Mean PS (average number of placental scars) approximates *in utero* litter sizes among those pregnant.

[2] For this study, separate PS figures were also presented for "intermediate" hare population levels: with PS - yearlings 0% (6), adults 46% (26), Mean PS - adults only, 3.9.

[3] Literature sources: 1) Brand and Keith 1979, 2) Parker *et al.* 1983, 3) Quinn and Thompson 1987, 4) O'Connor 1984, 5) Stephenson 1986.

[4] O'Connor (1984) includes reference to and re-analysis of data previously presented by Nava (1970) and Berrie (1974).

Table 2-6. Records of litter size in free-ranging North American lynx, in relation to snowshoe hare abundance

LOCATION / Study Years	Method[1]	HARES ABUNDANT Litter Sizes Numbers	Mean	HARES INTERMED. Litter Sizes Numbers	Mean	HARES SCARCE Litter Sizes Numbers	Mean	LIT[4]
ALBERTA								
1964-68	S			3,3,4,4	3.5			1
1971-75	S	3,4	3.5	1,1,2	1.3			2
MANITOBA								
1978-79	R	2,2,1	1.7					3
NOVA SCOTIA								
1977-80	R,S			3,3	3.0	3	3.0	4
ALASKA								
1968-70	O	2,2,4,5[2]	3.3					5
1984-85	R					2	2.0	6
WASHINGTON								
1986-87	R			3,4,3,1	2.8[3]			7
YUKON								
1987				3,4	3.5			8
Means By Hare Abundance			2.78		2.80		2.50	

[1] Primary study method: S = snow-tracking, R = radio-tracking, O = incidental observations.

[2] The litter of 5 involved very small kittens in a natal den.

[3] Relative hare abundance levels were not specified in the Washington study, but based on the general account of hare occurrence, neither high nor low would appear to be applicable.

[4] Literature sources: 1) Nellis *et al.* 1972, 2) Brand *et al.* 1976, 3) Carbyn and Patriquin 1983, 4) Parker *et al.* 1983, 5) Berrie 1974, 6) Stephenson 1986, 7) Koehler 1987b, 8) Ward and Slough 1987.

Clearly, it is the absence of litters in several winters, not the size of litters when they were present, that is of major importance in the context of long-term recruitment. Brand *et al.* (1976) note that at least two litters were observed in the study area in July 1973, but they were apparently no longer present the following winter. Unfortunately, the possibility that the females involved moved the litters outside the study area can not be ruled out in that case. Koehler (1987b) documented summer losses of six of seven kittens (86%) produced by two radio-collared females in his Washington study area in 1986. The relationship of those losses to prey abundance is not clear, since the report cited is preliminary and such details were not presented. However, it serves to indicate how poorly placental scar counts or early observations of litters might predict recruitment in some years.

The smallest average litter size indicated in Table 2-6, 1.67 for three litters in Riding Mountain National Park, Manitoba, occurred during a period of hare abundance (Carbyn and Patriquin 1983). Possibly all three females were yearlings and/or were recent dispersers from areas with low hare numbers. Mech (1980) was aware of two cases of female lynx bearing young in Minnesota, but only 1 of his 14 livetrapped females had obviously nursed, and only 2 of 22 uteri examined showed placental scars. Most of the animals examined were believed "young" but, by weight, mostly older than yearlings. Since Mech (1980) felt that most of the lynx involved had moved in from Canada, there is some indication that such dispersal populations are less productive than resident populations elsewhere.

Finally, since the largest litter recorded in the literature appears to be the five very small kittens found in a den in Alaska (Berrie 1974), it seems worth reporting an observation of a group of six animals, believed to have been a female with five large kittens, during an aerial moose survey near Level Mountain, northwestern British Columbia, 2 March 1980 (Hatler, unpubl.).

2.5.3 Mortality

There is little direct information on the extent or causes of natural mortality of lynx. Modeling from province-wide harvest data and observed population densities on the Rochester study area, Brand and Keith (1979) projected "nontrapping" mortality rates of 54-68% in 4 of 5 years when hares were low and/or declining, and 34% in the other year (1974). For the years 1972-74, when hares were both low and progressively declining, projected nontrapping mortality rates for kittens and adults, respectively, were 65%- 95%-88% and 38%-35%-7%. Separate non-trapping mortality rates during years of hare abundance were estimated at 20-60% for kittens and 20-50% for adults, based on observed changes in numbers on the study area. Other studies have suggested far lower values for natural mortality. Based on age and sex structure of the harvest, Quinn and Thompson (1987) projected average annual mortality rates of about 38% in Ontario during an increase phase, but concluded that almost none of it was due to nontrapping causes.

As implied in the previous section, kittens may be subject to considerable early mortality that is believed to be mostly nutrition-related (Nellis *et al.* 1972; Brand *et al.* 1976; Brand and Keith 1979). Documentation of adults in poor condition during hare lows (Section 2.4.6), and the report of a radio-collared adult that is believed to have starved to death (Ward and Krebs 1985) suggests that nutrition could also be important in survival of adults. Severe winter weather has also been suggested as a contributing factor in at least one year (Nellis *et al.* 1972). Reports of other causes are rare. A record of a "young" lynx killed by a larger one (Elsey 1954) was described in Section

2.4.9. In addition, Koehler (1987b) attributed the loss of a radio-collared adult male to predation (predator not specified), and a collared adult female monitored by Koehler *et al.* (1979) was apparently killed by a cougar. In Alaska, a wolverine killed a lynx in a livetrap (Berrie 1974), and Iurgenson (1955) described an incident in which two wolves killed and ate a European lynx.

However, by far most of the mortality documented for marked research animals has been to human-related causes (Table 2-7), and that result has been viewed as confirmation that man is a dominant factor in lynx population dynamics (Ward 1985) and that lynx are particularly vulnerable to over- exploitation (e.g, see Bailey *et al.* 1986, 1987). The major considerations in relation to management are: a) whether the observed high proportion of trapping mortality among marked samples is representative, and b) whether human-caused losses are additive or compensatory to natural losses.

The question of whether the observed high mortality among the marked research animals is representative of that in the general population has been critically examined by Ward (1985, 1987). He concluded that the mortality rates suggested by Brand and Keith (1979) and by losses of radio-collared animals in studies such as his own (Table 2-7), were unrealistically high, causing modeled populations to decline more quickly and deeply than observed among real populations. He noted that small overall sample size (only 36 tagged lynx in all studies to that time combined) might be part of the problem, and that it might be inappropriate to assume that results on study areas, which are usually accessible by design, might also represent results in more remote areas. I would add that a sample of marked (and therefore trapped) research animals might be biased in the same manner as harvest samples, largely composed of insecure individuals predisposed to trapping. Thus, while it appears that overall harvest rates cannot be as bad as the tagging studies have suggested, the arguments presented do not negate Ward's (1985) conclusion that man currently appears to be the single most important mortality agent for managed lynx populations. The important consideration seems to be whether the lynx that are trapped during low population levels would otherwise survive.

Brand and Keith (1979) is the widely cited primary source for the conclusion that trapping mortality of lynx tends to be additive. Theirs is the only study that has attempted to model population changes from combined harvest and field data, but the field sample sizes were relatively small and there was no way to distinguish between unreported mortality and dispersal. Nontrapping mortality was essentially defined as that occurring in May to November. It seems apparent, from all studies presenting data on the subject, that nutrition-related kitten mortality is common, and that most occurs in that time period. However, there is no good evidence for similar scheduling of adult natural mortality and, as described above, no "regular" causes have been identified. Nutritional problems among adults would appear to be less likely in summer than in winter because metabolic requirements should be less at higher temperatures and because, as shown in Section 2.4.1 (food), a wider range of foods is both available and used by lynx in summer. Further, the only documented case of apparent starvation of an adult is believed to have occurred in late winter (Ward and Krebs 1985).

Table 2-7. Fates of individually marked lynx from North American research projects, as recorded in the literature. Ideally the available information should be summarized by sex, age, hare abundance levels, and possibly time period between first and last contacts, but differences in data presentation between sources made such a compilation impossible

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A) Animals marked only for visual recognition (eartags, tattoos, collars), thus detection of mortality other than that by humans unlikely.

Alberta, 1964-68: Hares low-increasing (Nellis *et al.* 1972).

Mortality documented for 3 of 9 marked animals in 1964-65 (fates of other 6 unknown), and 1 of 8 in 1965-68 (3 recaptured after at least 1 year, but the final fate of those and of the 4 others unknown): Total detected mortality = 4 of 17 (23.5%), all human-related.

B) Animals radio-collared, potentially allowing detection of all mortality.

Manitoba, 1978-80: Hares high (Carbyn and Patriquin 1983).

All of 3 collared adults, a male and two females, were trapped; the male had been eartagged in 1976, thus it survived as an apparent local resident in the study area for at least 50 months; the collared females each had two kittens (total 4, of which 1 was trapped and the fates of 3 were unknown); the adult females were both trapped within about 3 months after being collared. Total detected mortality = 3 of 3 (100%), all human-related.

Nova Scotia, 1978-80: Hares declining (Parker *et al.* 1983).

Three collared animals, an adult male, adult female, and a juvenile (yearling?) female, were all trapped early in the first open season to which they were exposed. Total detected mortality = 3 of 3 (100%), all human- related.

Yukon, 1982-84: Hares declining and low (Ward 1985).

A collared male juvenile was trapped within a few weeks of capture; among collared adults (at least 1 year old), 3 of 5 males and 3 of 5 females were trapped, and 1 other female apparently starved. Total detected mortality = 8 of 11 (72.7%), of which 87.5% was human-related.

Alaska, 1982-84: Hares high (Bailey *et al.* 1986).

The total sample over two years was apparently 12 animals, sexes and ages not specified. Mortality rates, based on lynx days, increased from .44 (2 mortalities) to .86 (5) between the 1982-83 and 1983-84 trapping seasons. Sex and age specific mortality rates were .88 for adult males (3), .45 for adult females (2), .78 for all adults (5), and .77 for juveniles (4). The 9 mortalities included 6 animals that were trapped and 3 juveniles that died after their mothers were trapped. The total detected mortality was 9 of 12 (calculated by the authors as 90% on the basis of lynx days), all human- related.

Table 27, continued

Alaska, 1984-87: Hare levels not specified (Bailey *et al.* 1987).

The collared sample included 13 in an area closed to trapping and 10 in an area with an open season (sexes and ages not specified). Over the 3-year period, 10 mortalities (8 trapping, 1 vehicle collision, 1 unknown) and 6 "unknown fates" were recorded. Most mortalities were in the closed area, but details not provided. Total detected mortality = 10 of 22 (45.5%), of which at least 90% human-related.

Alaska, 1982-86: Hares generally low (Stephenson 1986).

All of 4 collared animals (2 males, 2 females--ages estimated at 2.5 years for 1 male and 1.5 for the other 3), were trapped within a few months of capture in 1982. Total detected mortality = 4 of 4 (100%), all human-related.

In another study area, 1984-86, all of 3 males apparently survived and remained in the study area, while 2 of 4 females were trapped and 1 dispersed. Total detected mortality = 2 of 7 (28.6%), all human-related.

Minnesota, 1972-75: Hares considered high (Mech 1980).

The sample of radio-collared animals included 4 males and 10 females, all believed to be young adults (only 1 of the females believed parous); 7 of the 14 (sexes not specified) were killed by humans (trapping, shooting, and vehicle collision mentioned, but not itemized), and the fates of the other 7 were unknown. Total detected mortality = 7 of 14 (50%), all human-related.

Washington, 1981-87: Hare abundance not specified (Koehler 1987b).

The progress report available did not specify sample sizes, sex and age characteristics, or causes of death; presumably the deaths of at least two animals trapped in British Columbia are included. In an area closed to trapping, the mortality rate among collared animals was 21% in 1981- 83, 27% in 1986, and 0% in 1987. A detailed report on findings through 1983 is in preparation (D. Brittell, pers. comm.).

Given the absence of any substantive documentation of summer mortality among adults, the observed summer losses of adults on the Rochester study area are most easily explained in terms of movements, and particularly since the apparently nutrition-related dispersals documented in the Yukon by Ward and Krebs (1985) occurred during the snowfree season. Although survival was poor among the Yukon dispersers, they died in the trapping season not in summer, thus their losses may, in fact, have been compensatory (see discussion in Ward 1985). Studies have shown that trapping may be selective in timing and method for particular classes of animals (Parker *et al.* 1983; Quinn and Thompson 1985, 1987), and that poor condition (such as occurs during periods of low hare abundance) may predispose individuals to trapping (Brand and Keith 1979; Ward and Krebs 1985). To know whether trapping mortality of such animals is additive or compensatory, we need to know how well they would survive and produce in the absence of trapping. The important point, as outlined by Ward (1985), is that if trapping mortality is highly compensatory during periods of hare scarcity, continuing to harvest at such times may have little effect on subsequent lynx population recovery.

2.5.4 Abundance and Composition of Lynx Populations

Most of the papers indexed under "poptrend" and "popcomp" provide only general reference to populations, referring mostly to numbers and composition of animals in the harvest rather than on the ground. The focus here is only on the latter, since harvest characteristics are discussed in Section 2.6.2, under management.

Numbers - Data on numbers of wild lynx have been gathered only in winter, mostly by attempting to account for all animals within a particular study area through intensive telemetry and/or snowtracking (ground and aerial). Expressed as lynx/100 km², the following densities have been documented.

1) On a 130 km² study area in **north-central Alberta**: 2.3 at low hare abundance up to 10.0 at the high (Brand *et al.* 1976).

2) On a 60 km² study area on **Cape Breton Island, Nova Scotia**, at high hare levels: 20.0 (Parker *et al.* 1983).

3) In 570, 777, and 971 km² portions of the same study area in **interior Alaska**, all at a low in the hare cycle: 1.8-5.7, 1.8-4.2, and 1.4-3.4, with the highest values in early winter 1983-84 and the lowest in late winter 1984-85 (Stephenson 1986).

4) In 2465, 807, and 1362 km² portions of the **Kenai National Moose Range, Alaska**, during high hare levels: 1.0, 2.3, and 2.3 (Bailey *et al.* 1986).

5) In a 259 km² survey area in **southcentral Alaska**, hare levels not specified: 5.07 plus/minus 4.32 (Schwartz and Becker 1987).

6) In an area of 648 km² in **northern Washington**, hare levels not specified: 2.3-3.1 (Koehler 1987b).

The very high density described for the Nova Scotia study may be an artifact of that island situation and/or may represent concentration in the particular habitats composing the small study area. There is therefore some doubt as to whether it may legitimately serve as an upper limit of lynx abundance that can be expected over larger areas elsewhere. At low population levels, densities are fairly consistently in the 2-4 animals/100 km² range, although as indicated by Stephenson's (1986) results, applicable figures depend upon how the study area is described. Elimination of habitats rarely used by lynx results in increasing the apparent density. The low density values obtained in the Kenai area, only 2.3/100 km² in the best habitats during the hare peak, were offered as documentation of an apparent overexploitation of lynx in that area. The Washington results are not directly comparable to the others, since they apparently involve only adults. At least four young were reportedly present on the study area in one year, thus density values of 3.0-3.8 may apply there. Such values are comparable to those observed at low hare density in Alberta (Brand *et al.* 1976).

Iurgenson (1955) indicated that lynx populations in the U.S.S.R. increased about 3-fold between lows and highs in the hare cycle. In Alberta, there was a 4.3-fold difference between low and peak lynx numbers on the Rochester study area (Brand and Keith 1979), and a 3.8-fold difference over one complete hare cycle (Keith *et al.* 1977). The suggested 12.5-fold difference for the B.C. Provincial population, 20 000 to 250 000 (Goodchild and Munro 1980) is therefore probably out of line. The B.C. estimates are apparently based on harvest records, assuming that harvests constituted about 10% of existing populations. As shown by Ward (1985), lynx populations can sustain harvests of up to 30% and may be subject to higher levels during peak harvest periods. Brand and Keith (1979) noted that the 4.3-fold increase in the lynx population at Rochester was accompanied by a 20-fold increase in the provincial harvest. Their projected provincial population for spring 1972-73, a near peak harvest year, was about 127 000 (including newborn kittens), but that may be biased upward if, as suggested by Ward (1985), their mortality estimates were too high. Since Alberta probably has more high quality lynx/hare habitat than B.C., particularly boreal forest, it probably supports more lynx at high population levels. Thus, the upper B.C. estimate (250 000) is unrealistically high.

Composition - Brand *et al.* (1976) distinguished kittens and adults during their intensive snowtracking surveys, and were able to provide some indication of population composition in terms of those two classes. They documented no kittens in their study area when hares were scarce, but found them composing 67% of 9, 54% of 13, and 40% of 10 in years when hares were increasing, high, and decreasing, respectively. The presence of yearlings in the harvest indicated that kittens were not completely absent in Alberta during the low hare years, but Brand and Keith's (1979) model indicated that they might constitute as little as 3% of the population at those times. The model also supported the study area observations that two-thirds of the population might be kittens when hares were more abundant. With hares declining, kittens composed 55% of 11 lynx identified by Parker *et al.* (1983) on their Nova Scotia study area. In Washington, kittens apparently composed 0 and 20-25% of a study area population in two consecutive years (Koehler 1987b).

Aspects of sex ratio in living populations are little known. The sex of single adults can not be determined by snowtracking, but assuming all litters described by Brand *et al.* (1976) were accompanied by their mothers, females composed at least two of three, two of six, and three of six adults identified on the study area in the three years when kittens were present. There were two of

each sex and one unidentified among five adults identified by Parker *et al.* (1983). The sex composition of lynx populations may vary with the stage of the cycle and/or with harvest intensity (Section 2.6.2), and may be an important factor in population growth (O'Connor *et al.* 1987), thus more specific field information is needed.

2.5.5 Population Regulation

Reviewing felid population dynamics, Keith (1974) concluded that lynx populations were not limited by social behavior (territoriality) because of their dependence on a fluctuating and unstable prey base--the cyclic hare. He argued that there is little point in defending an area that contains insufficient resources. Low recruitment of lynx populations during hare lows has been well documented, and nutrition-related low survival of kittens has been implicated as a major factor (see Section 2.5.2). However, Brittell (1987) believed that the low lynx population densities observed on his Washington study area, where hare populations may be more stable (G. Koehler, pers. comm.), were the result of regulation by the social system.

The apparent low production and/or survival of kittens in the Washington study area (Koehler 1987b) has yet to be explained in either a nutritional or social context. However, the area differences in opinion about the population significance of social behavior are probably not contradictory when viewed in the context of nutritional status. The evidence compiled by Ward and Krebs (1985) also led to the conclusion that lynx are not territorial, but they qualified it with the phrase "...at least during the period of decline of snowshoe hare density." They cite evidence of range abandonment of other, more demonstrably territorial felids (including bobcats) in the face of local prey declines, and conclude that "If any behavioral spacing mechanism exists in lynx populations, it is easily overridden by proximate environmental factors such as snowshoe hare density."

Thus, the situation in British Columbia could vary between that observed by Ward and Krebs (1985) to the north, where major hare fluctuations are apparent, and that recorded by Brittell (1987) and Koehler (1987b) to the south, where the prey base may be more varied and/or stable.

2.6 POPULATION MANAGEMENT

2.6.1 Economic Considerations

As is the case over most of its range (McCord and Cardoza 1982), the lynx in British Columbia is managed primarily for commercial use as a furbearer (Goodchild and Munro 1980). Table 2-8 outlines the pattern of economic returns from lynx trapping in British Columbia over the past four decades. The most recent peak harvest (1982-83) yielded a total dollar return that was more than 10x higher than a harvest twice as large in 1962-63. Further, at close to $2 million, that return constituted almost half of the total B.C. fur revenue in that year. The 1984-85 harvest, though only a quarter of that in 1982-83, nevertheless provided trappers with more than $1 million. Almost twice as many pelts three decades earlier (1954-55) brought only $21 000. While the above comparisons are not strictly valid, because of the higher buying power of a dollar in times past, recent trends appear positive and help dramatize the present importance of lynx to society. However, partly because harvest data have long been the primary indicator of population status and

Table 2-8. Value of lynx pelts and harvests in British Columbia, 1950-1987[1]

Trapping Season	No. Lynx Sold	Average Value ($)	Lynx Total Sales ($)	Total Fur Sales ($) (All Species)	Lynx Proportion (%)[2]
1949-50	515	8.90	4,584	949,975	0.5
1950-51	1399	12.33	17,250	1,589,223	1.1
1951-52	870	4.35	3,785	812,466	0.5
1952-53	2126	5.15	10,949	708,688	1.5
1953-54	1517	3.25	4,930	567,785	0.9
1954-55	3132	5.15	16,130	774,570	2.1
1955-56	2239	6.12	13,703	572,595	2.4
1956-57	1608	6.76	10,870	399,117	2.7
1957-58	1569	7.58	11,893	393,345	3.0
1958-59	1304	12.52	16,326	421,694	3.9
1959-60	4058	16.00	64,928	812,080	8.0
1960-61	3463	9.00	31,167	646,538	4.8
1961-62	4797	8.73	41,878	629,558	6.7
1962-63	12570	13.53	170,072	922,357	18.4
1963-64	7225	13.75	99,344	763,562	13.0
1964-65	4660	20.27	94,458	778,339	12.1
1965-66	2195	35.00	76,825	776,542	9.9
1966-67	2264	25.63	58,026	671,061	8.6
1967-68	4737	31.63	149,831	805,551	18.6
1968-69	1022	32.91	33,634	649,969	5.2
1969-70	1497	23.83	35,674	647,561	5.5
1970-71	1927	34.27	66,038	682,035	9.7
1971-72	4034	38.61	155,753	742,430	21.0
1972-73	8641	86.10	743,990	1,741,680	42.7
1973-74	8719	93.92	818,888	1,883,893	43.5
1974-75	5190	131.52	682,589	1,349,773	50.6
1975-76	3084	259.30	799,681	1,832,071	43.6
1976-77	1294	224.27	290,205	2,095,691	13.8
1977-78	1119	315.26	352,776	2,109,335	16.7
1978-79	1577	382.25	602,808	3,627,909	16.6
1979-80	2848	214.29	610,298	4,035,574	15.1
1980-81	3696	297.16	1,098,303	3,633,304	30.2
1981-82	5463	276.98	1,513,142	3,382,737	44.7
1982-83	6264	305.14	1,911,397	3,827,978	49.9
1983-84	2760	354.91	979,552	3,584,709	27.3
1984-85	1668	672.18	1,121,196	4,890,771	22.9
1985-86	1206	658.73	794,428	3,172,599	25.0
1986-87	1050	540.75	567,788	5,798,571	9.8

[1] Data for 1949-50 through 1978-79 from Statistics Canada Records (Fur Production of Canada Series), and the remainder from files of B.C. Ministry of Environment and Parks, Wildlife Branch, Victoria).

[2] Percentage of total B.C. fur sales due to lynx.

trend in most jurisdictions, the influence of changing pelt prices on trapping pressure and harvest levels is a factor that greatly complicates management. That factor has loomed particularly important in the past decade of high pelt prices (O'Connor 1984; Todd 1985; McKay 1985; Bailey *et al.* 1986; Quinn and Thompson 1987; ADFG 1987).

While the pattern of increasing and continued high average pelt prices is shown clearly in Table 2-8, that compilation may understate the case. The trapper contemplating a fresh lynx track on his trapline is most likely visualizing the top rather than average price, over $1000 in recent years, which might mean a boost of 10-50% or more to his year's income. As discussed by Todd (1985) and McKay (1985), it would be difficult not to set a trap under such circumstances. That is particularly true when the alternative to potentially banking up to $1000 is not all that clear. There are no guarantees that a) the habitat will remain intact, b) the lynx in question will not be trapped elsewhere, c) if it survives and stays in the area, it will contribute to increased numbers in the future, or d) the increased numbers will be worth as much either collectively or relatively. That same lynx may be worth far less next year, particularly if populations are increasing and the competitive demand for lynx fur is reduced.

Based on observed patterns in Alaska through the 1960's, Burris (1971) suggested that "...low success by hunters and trappers in the years of low lynx populations will result in a self-regulating situation." However, it seems likely that the law of diminishing returns does not apply at today's pelt prices, and that the risk of overexploitation could therefore be high.

2.6.2 Harvest Characteristics

As stated or implied in previous sections, the primary management- oriented information on lynx population trends and status everywhere has been harvest data. It is not possible to review and assess all of that information here. Following paragraphs a) describe historic and recent B.C. harvest patterns in relation to those from other selected areas, b) and c) attempt to establish generalities of harvest composition as reported in the literature, and d) discuss the matter of overexploitation as it may apply to lynx in B.C.

a) *Numbers* - Figure 1 depicts the recorded harvest of lynx in British Columbia since the 1919-1920 trapping season. Although the accuracy and consistency of data collection and compilation over the years may be questionable, the general patterns are similar to those observed elsewhere. The 10-year cycle shows clearly, with peaks at mid-decade from the 1920's through the 1950's, but changing to the first third (1962-63, 1973-74, and 1982-83) thereafter. The general amplitudinal pattern of peaks--moderately high in the 1920's, low in the 1930's through 1950's, high in the 1960's and 1970's, then decreasing in the 1980's--essentially parallels that observed in Alberta (Todd 1985). The pattern in Alaska is somewhat similar, particularly in the case of the low amplitude peaks of the 1930's, 1940's and 1950's, although peaks in the 1920's and earlier were considerably higher than any since (ADFG 1987).

The 1962-63 peak of 12 570 is apparently the highest single-year harvest total that has been recorded for British Columbia. The only other years with harvests over 8000 were consecutive, in 1972-73 and 1973-74, and their combined total of 17 360 might better represent the "peak" for the 1970's cycle. While there may be a temptation to consider the 1960's and 1970's results as indicative of the way things "should be", such expectations might be unrealistic. Further, as

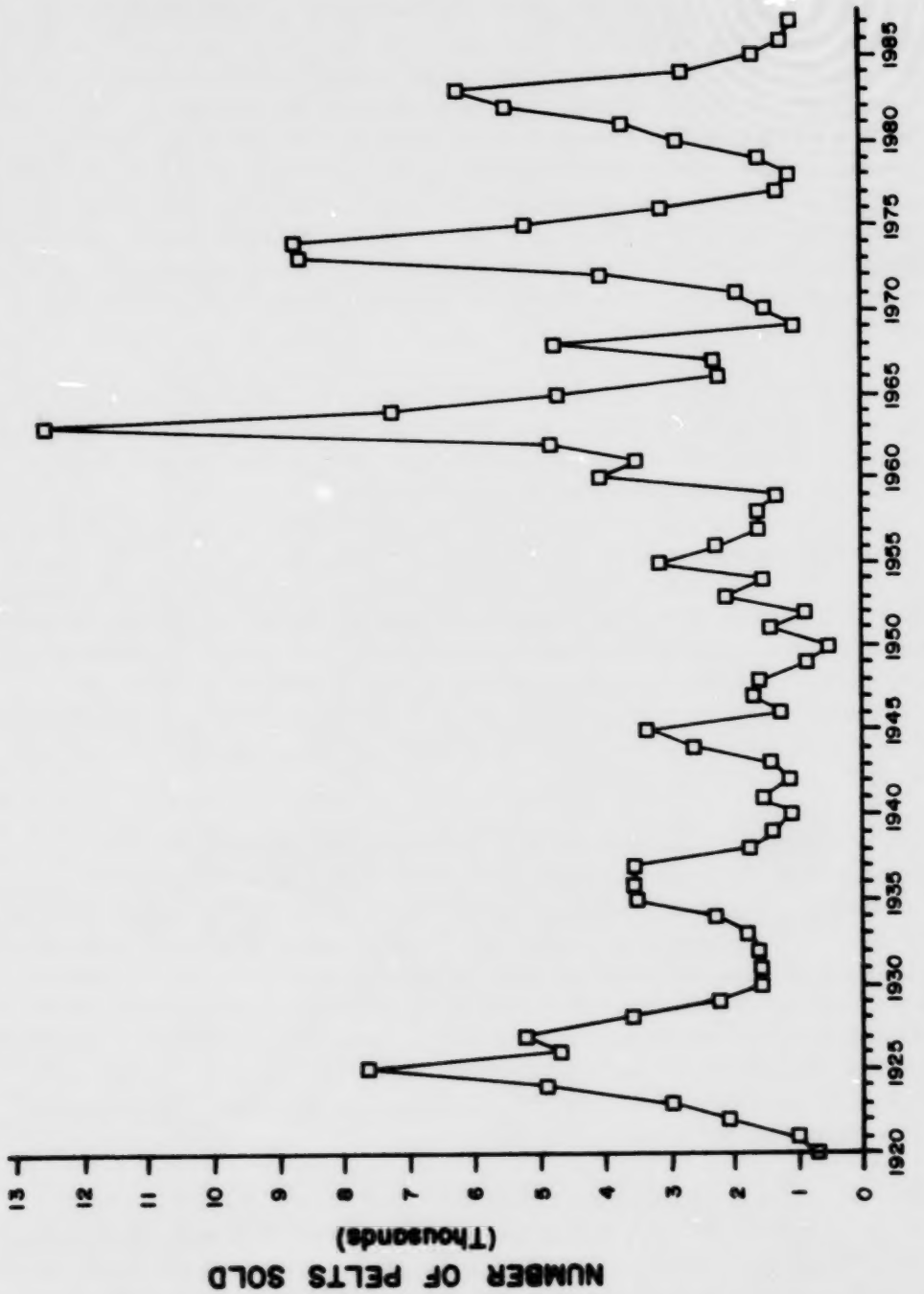


Figure 1. The lynx harvest in British Columbia, 1920 - 1987.

illustrated by the 1962-63 data in particular, a high peak harvest does not necessarily translate to high revenue (Table 2-8).

Figure 2 depicts the geographical distribution of the Canadian harvest in the early to mid-1970's, which includes a block of three years (1970-71 through 1972-73) with a combined harvest of almost 150 000 animals (Table 2-9). The major feature of the early 1970's data is the extreme dominance of the Alberta catch, averaging over 35% of the total in the three peak years. British Columbia led the harvest with about a quarter of the total in the 3 years after Alberta's decline, and ranked No. 2 for the 6-year period as a whole (Table 2-9).

The British Columbia harvest has been compiled by location only for the two most recent seasons, and only incompletely (78% of the total in 1985-86 and 68% in 1986-87). Therefore, if there are regional differences in cyclic amplitude and timing, they are yet to be described. In the 2 years indicated, by far the largest proportion of the provincial harvest was in the Omineca-Peace Region (Figure 3), probably mostly in the northeast corner. That area is an extension of the low-lying boreal forest of adjacent Alberta and the NWT, and is very accessible owing to an extensive system of seismic lines.

b) *Composition (age)* - There have been no studies on the age structure of lynx harvests in British Columbia. However, results of work elsewhere are fairly consistent and are probably applicable. The harvest tends to be dominated by young animals when hares are abundant and lynx populations are increasing or high, or when overexploitation has removed most of the adults. When hares are scarce, the proportion of adults (2 years and older) and average age of the harvest increases. The most comprehensive study appears to be that of O'Connor (1984), based on a sample of over 3000 carcasses (all females) collected over one complete population cycle. A complete review is not possible here, but for 1091 animals caught in winters following years of hare abundance, the percentages of kittens, yearlings, and adults were 34.6, 41.5, and 23.8, respectively, while comparable figures for 288 animals taken after hare declines were 10.1, 11.4, and 78.5. The bias resulting from absence of males in those samples is not known. Following are the results of other major studies to date:

Hares Decreasing/Low

Alberta (Brand and Keith 1979): During a five-year period of hare decline, from high to low, mean ages of harvest samples (N=52,403, 284,202,32) were 1.6, 1.9, 2.3, 3.5, and 3.6. The proportion (%) of three age classes changed as follows:

kittens - 31, 12, <1, 0, 0.
yearlings - 54, 58, 44, 1, 12.
adults - 15, 30, 56, 99, 88.

Nova Scotia (Parker *et al.* 1983): Age class percentages among samples (N=42,57,55) over three years were:

kittens - 29, 9, 2.
yearlings - 52, 67, 39.
adults - 19, 22, 59.

Table 2-9. Geographical distribution of the lynx harvest in Canada during the 1970's cyclic peak and decline

	1970-71		1971-72		1972-73		1973-74		1974-75		1975-76		ALL	
Canada Totals[1]	42,487		53,243		53,439		35,281		20,722		13,071		218,243	
	Proportion of Total, and Rank[2]													
	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Alberta	36.2	1	42.8	1	33.8	1	22.8	2	16.6	3	14.0	3	31.9	1
British Columbia	4.5	5	7.7	5	16.2	2	24.7	1	25.0	1	23.3	1	14.5	2
Manitoba	14.7	3	13.7	2	8.5	5	4.2	7	3.8	8	5.4	7	9.6	4
Newfoundland	1.1	8	1.6	9	1.2	9	1.7	9	0	10	2.9	9	1.4	9
Northwest Terr.	12.4	4	10.3	4	5.2	7	2.9	8	6.0	7	4.4	8	7.5	6
Nova Scotia	0.1	10	0.1	10	0.1	10	0.1	10	0.1	9	0	10	0.1	10
Ontario	4.5	6	4.6	6	9.6	4	10.5	4	9.3	4	8.8	5	7.5	7
Quebec	3.8	7	3.5	7	6.4	6	17.7	3	21.4	2	22.4	2	9.4	5
Saskatchewan	21.7	2	13.6	3	14.8	3	7.0	6	9.1	5	13.0	4	14.0	3
Yukon Terr.	1.0	9	2.1	8	4.2	8	8.4	5	8.7	6	5.6	6	4.3	8

[1] Annual lynx harvest data from: Deems, E.F., Jr., and D. Pursley (eds). 1978. North American Furbearers: Their management, research and harvest status in 1976. Internat. Assoc. Fish and Wildl. Agencies and Maryland Dep. Nat. Resources. 171pp.

[2] Percent of total Canadian lynx harvest attributable to each jurisdiction in each time period; ranks 1-10 are from the highest to lowest provincial or territorial contributions.

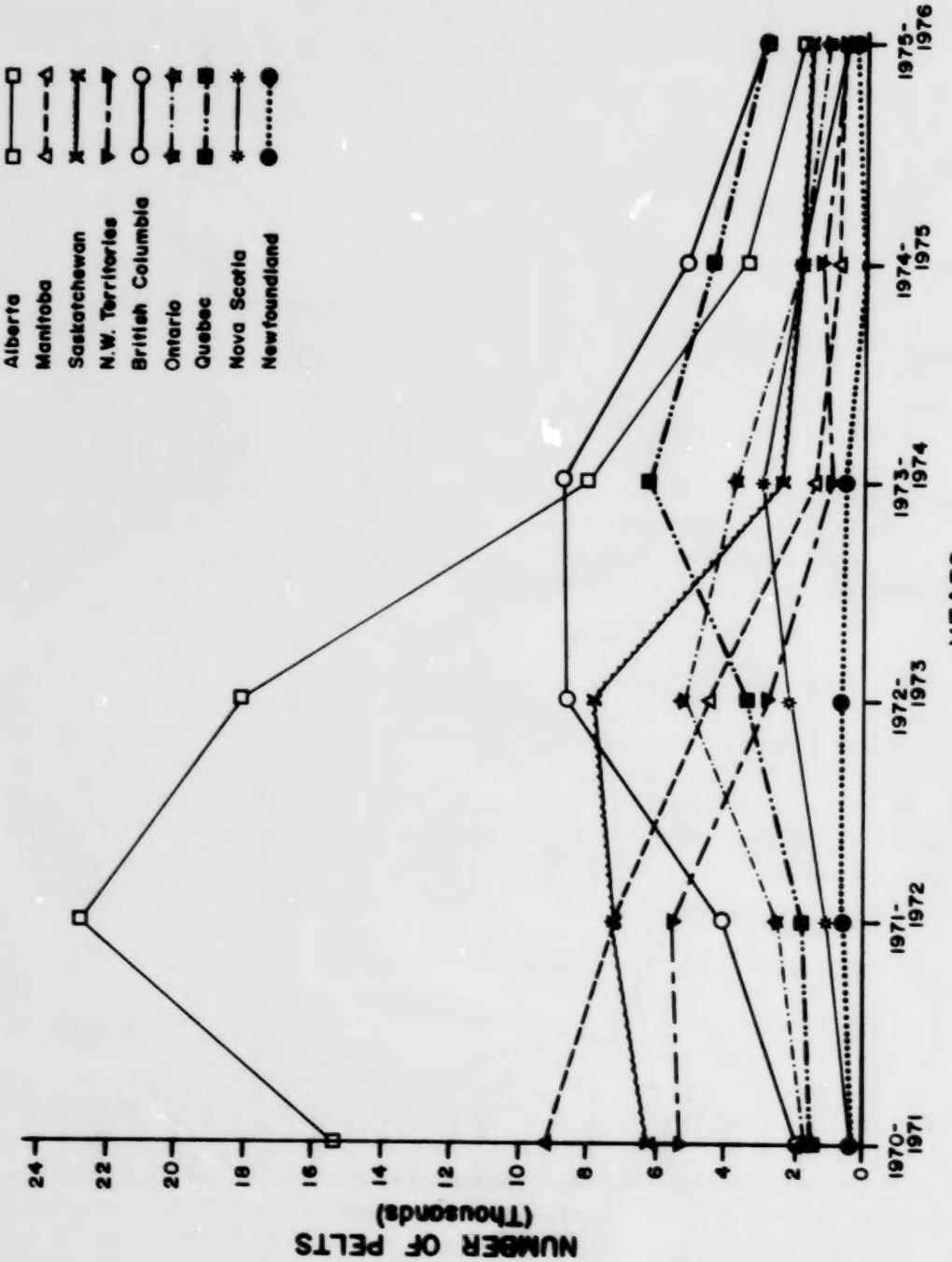
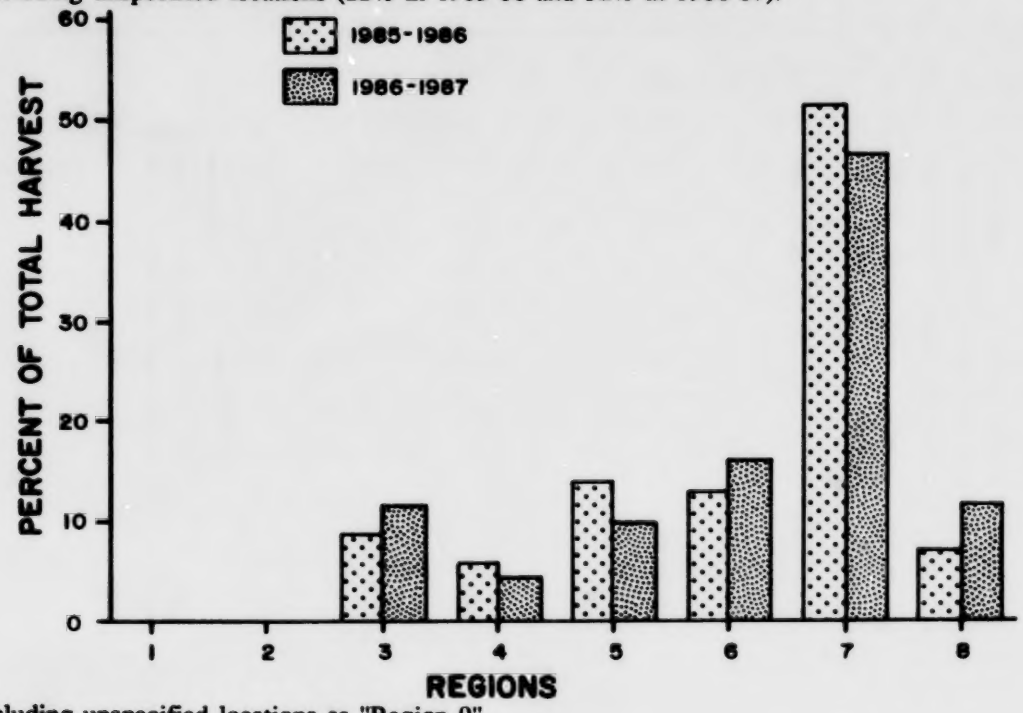


Figure 2. Distribution of the lynx harvest in Canada in the early to mid-1970's.

A. Excluding unspecified locations (22% in 1985-86 and 32% in 1986-87).



B. Including unspecified locations as "Region 9".

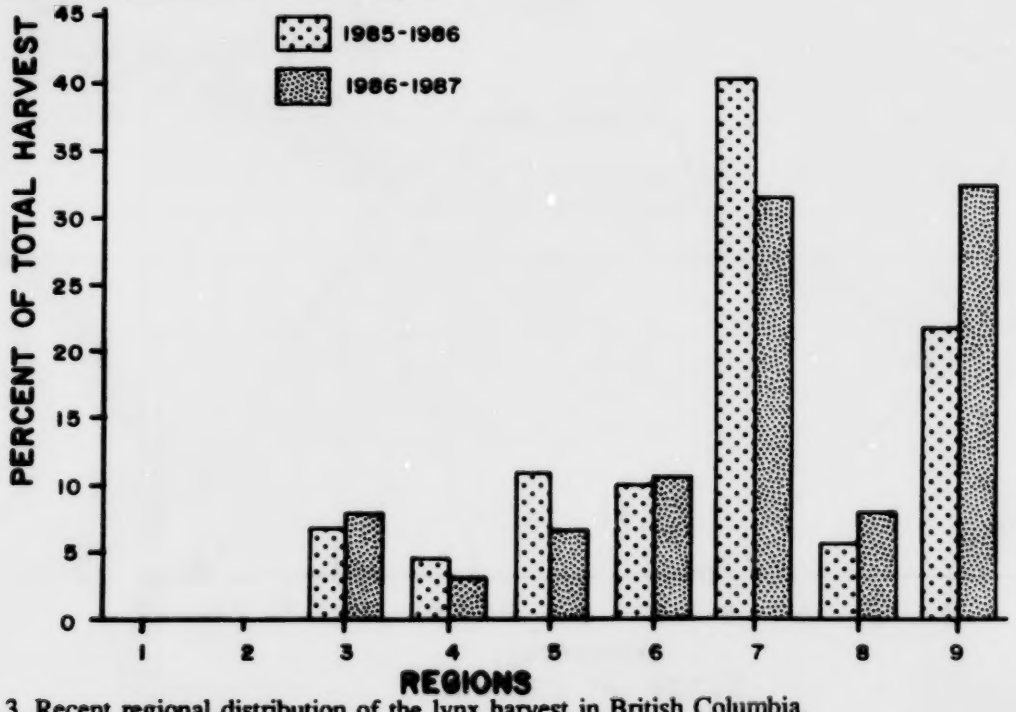


Figure 3. Recent regional distribution of the lynx harvest in British Columbia.

Alaska (Berrie 1974): Over 3 years, with hares mostly low but possibly increasing locally (see O'Connor 1984)--samples of 1087, 1229, 222, heavily biased to females, were aged as follows:

kittens - 13, 10, 0.
yearlings - 50, 26 9.
adults - 37, 64, 91.

Hares Increasing/High

Ontario (Quinn and Thompson 1987): For a lumped sample of 993 specimens collected over 3 years, age class percentages were 19% for kittens, 49% for yearlings, 26% for adults, and 6% for an unknown (non-kitten) component.

Alaska (Berrie 1974): the 3-year pattern (N=166,339,391, not biased to females as in 3 previous years) was:

kittens - 3, 4, 30.
yearlings - 4, 4, 23.
adults - 93, 89, 47.

Hares High, Lynx Over-exploited

Alaska (Bailey *et al.* 1986): Mean ages of an apparently incomplete sample of harvested males and females were 1.9 (N=30) and 2.3 (N=31), respectively.

Although the general pattern seems clear, there are some complicating factors. Perhaps the most important is the regional disparity documented by O'Connor (1984). Although lynx populations in all of three sub-units in interior Alaska responded similarly to changes in hare abundance, they were not exactly in phase and they exhibited significant differences in age distribution in 6 of 10 winters. In the Yukon 4 and 5 years after the hare decline, the kitten component of harvest samples from Dawson was 1.7-fold and 2.1-fold greater than those from Whitehorse (Slough 1986; Ward and Slough 1987).

In addition, there is evidence that harvest age ratios vary within trapping seasons as well as between years and areas, with kittens increasing and yearlings decreasing in the harvest with the advancing winter (Parker *et al.* 1983; Quinn and Thompson 1985). Further, Brand and Keith (1979) showed that kittens may be under-represented in harvest samples by 50% or more. They found no kittens in the trapped sample from Alberta in 1974-75 (N=202), but that cohort constituted 12% of the harvest, as yearlings, in the following year (N=32). They and Parker *et al.* (1983) speculated that the observed patterns of kitten occurrence in the harvest may relate to some aspect of continuing maternal care at that time.

Although most age-related discussions have focussed on the younger classes, aspects of longevity may also be of some interest in management. Bailey *et al.* (1986) called attention to the harvest of two males, aged 10 and 12 years, in relatively remote, inaccessible sections of their Kenai study area. While the thrust of their discussion was to emphasize the extent of local trapping effort, those incidents also suggest that some individual animals may survive for long periods despite heavy trapping pressure. In their 3-year sample of about 150 lynx from Cape Breton Island, Parker *et al.* (1983) found at least two ll-year old animals and a few others that were 8-10 years old (sexes not given), but noted that no more than 6% of any one annual harvest sample was older than 6 years. Of 254 Ontario animals older than yearlings, ten (3.9%) were older than 6 years, and nine of those were females. The male was 7 years old, and only one of the females, a 13-year old, was older than 9 years (Quinn and Thompson 1987). Tumlison (1987) reports a record of a

22-year old lynx in captivity, and cites Nava (1970) in relation to a maximum age of 15 years in the wild.

Old animals, those whose ages approach or exceed the duration of one hare cycle, indicate the existence of a relatively secure segment of a local population. Given the generalization that lynx are "easy to trap" (McKay 1985; Bailey *et al.* 1986; Quinn and Parker 1988; and others), the size and identity of that segment, and its means for avoiding the harvest so long, are of management interest. Such animals may be maintained primarily in remote refugia (Ward and Krebs 1985; Todd 1985; Bailey *et al.* 1986), or may be behaviorally or ecologically less vulnerable than others. The characteristics of refugia are yet to be described--are they large or small, high or low, long-term or temporary, or all of the above? The existence of relative immunity of some individuals to trapping is speculative, but is consistent with findings, cited elsewhere in this section, that not all classes are equally trappable. Further, none of the intensive field studies to date were thought to have captured and marked all animals present, even when hares were low and/or declining (e.g., see Parker *et al.* 1983 and Ward 1985). Were those missed different from those captured?

c) *Composition (sex)* - It seems to be generally agreed that harvest sex ratio may not accurately reflect that in the population because of differential trapping vulnerability between the sexes, usually favoring males and especially among young age classes (Van Zyll De Jong 1963; Berrie 1974; Bailey *et al.* 1986; Quinn and Thompson 1987). However, Brand and Keith (1979) found no significant deviations from 50:50 by age, time period, or in relation to hare density in a sample of 943 trapped animals from Alberta, Brittell (1987) reported an equal sex ratio among his live-trapped animals, and Bailey *et al.* (1986) reported that females dominated in the harvest in 4 of 7 years in their Alaska study area.

For the immigrant population studied by Mech (1980) in Minnesota, there was some evidence that males declined first, leaving mostly females in the population. The sex ratio of about 40 live-trapped and harvested animals in 1972-73, when the animals first appeared, was near 50:50, but was 67% female (of 15) in 1973-74, and was all female (of 7) in the three years following. Quinn and Gardner (1984) speculated that, because of the higher vulnerability of males, overexploited populations might have "highly skewed adult sex ratios." Thus, the preponderance of females in the harvest despite a demonstrated lower trapping vulnerability of marked females, as observed by Bailey *et al.* (1986), might be further confirmation of the heavy trapping effect there. Further, a 50:50 harvest sex ratio such as documented by Brand and Keith (1979) might actually reflect a population sex ratio favoring females.

The population implications of an uneven sex composition are not clear. O'Connor *et al.* (1987) offered the preliminary conclusion, from modelling, that "small changes in sex ratio may substantially affect population growth during hare abundance". Specifically, populations high in females were the most productive (R.O. Stephenson, pers. comm.), thus there is a possibility that the implied male vulnerability and/or designed trapping selectivity could be positive for management. However, the proportion and age composition of males required for maximum breeding success are not known.

d) *Over-harvest of Lynx Populations* - To date, the most regular and significant source of mortality identified for lynx is the human harvest (Section 2.5.3). Previous paragraphs have

described what is known about lynx harvests in B.C. in terms of numbers, and have outlined some generalities about harvest composition, particularly in relation to hare abundance, that probably apply in at least some northern regions of the province. However, while the nature of the harvest is clearly of management interest, it is the effect of harvest that is the ultimate focus. Ascertaining that effect is difficult in that, although we may know what was taken, there is as yet no means and no precedent for knowing what was left (see Stephenson 1986; ADFG 1987). At present there is widespread concern that, stimulated by high pelt prices, continued intense harvest pressure during the low recruitment and low population stages of the lynx cycle will prevent or greatly reduce subsequent increases, and that declining harvests in the 1980's are symptomatic of that problem (Todd 1985; McKay 1985; Bailey *et al.* 1985; Anon. 1987).

Although they described their evidence as "circumstantial", clearly the best documentation of overexploitation of a lynx population is that of Bailey *et al.* (1986) on the Kenai National Moose Range, Alaska. They showed a pattern, through the 1970's and 1980's, of increasing trapping pressure, high trapping mortality of radio-collared animals, decreasing harvests, and continuing low densities of animals even at high hare levels. Ongoing comparative studies are apparently demonstrating better survival and some population response in an area closed to trapping (Bailey *et al.* 1987).

While the Kenai results seem clear, their applicability to lynx management in British Columbia is not. One basis for recommending more restrictive harvest regulations to the Kenai area is that it is situated on a peninsula, thus opportunities for population growth by dispersal from surrounding areas are greatly reduced (ADFG 1987). Also, under the unlimited entry system pertaining in Alaska, about 90 to 120 trappers have been operating in the Kenai study area in the past decade, an average trapper density of about 1/70- 90 km^2 assuming a homogeneous distribution, but apparently much higher than that in the best and most accessible habitats. In comparison, exclusive traplines in northern B.C. range in average size from about 200 km^2 in relatively accessible management units such as 6-08 to 750 km^2 or more in more remote units (e.g. 6-23 through 6-27), and many of those traplines are inactive or only lightly used. Without more specific information on numbers and distribution of trap sets (rather than trappers), actual comparisons of trapping pressure are not possible. However, it seems likely that the pressure observed in the Kenai area far exceeds the average that can be expected over most of B.C.

Regional and temporal comparisons of lynx harvests may be enhanced by expressing them in terms of "harvest densities", as done by Quinn and Thompson (1987) for three areas of northcentral Ontario. During a recent period of high recruitment and increasing population (1978-81), their harvest density figures (animals/100 km^2) ranged from 0.34 for a large area in the north to 1.71 in a small, more intensively-used area in the south. By comparison, again on a conservative assumption of complete and homogenous trapping pressure on the Kenai Refuge (Bailey *et al.* 1986), minimum harvest densities of 1.90 to 3.20 were attained there during the 1970's peak, but figures dropped to 0.50-0.60 during the 1980's. I have seen no comparable values for periods of low population, but B.C. Hydro (1981) based a compensation policy on expected harvest densities of 0.30, 0.90, and 1.80 in poor, moderate, and good habitats, respectively, at such times. During 1985-86 and 1986-87, with hare and lynx populations believed low but possibly increasing, harvest densities for five northern B.C. management units (6-24 through 6-28) ranged from 0.01 to 0.15 animals/100 km^2 (preliminary analysis only).

The case for the suspected recent overexploitation of lynx populations in Canada has been summarized in greatest detail, based on data from Alberta, by Todd (1985). With the 1970's peak harvests as the standard, the 1980's peak in Alberta was from 24% (3-year basis) to 40% (single peak year) lower. That harvest reduction occurred despite greatly increased pelt prices which, it is thought, should have stimulated continued high or increased trapping effort. It is therefore concluded that the reduced harvests probably reflect reduced populations. Other factors, including habitat changes, negative effects of the severe winter of 1981-82 on trapper effort, and a possibly lower amplitude hare cycle, are discussed as potential contributors to lower 1980's lynx populations and harvests, but they are not considered sufficient to have caused a 40% change. Evidence supporting overexploitation as the primary cause of the hypothesized 1980's population decline in Alberta include an extended peak (1979-80 through 1981-82), suggesting continued heavy pressure, and increased harvests during preceding cyclic lows. The single-year low in the 1970's was 70% and 180% higher than those in the 1960's and 1950's, respectively. Comparable figures for cumulative harvests during the four lowest years (4-year lows), were 60% and 130%. For Saskatchewan, the 1980's harvest decline was expressed in terms of the entire cycle, from 43 000 in 1965-74 to 22 000 in 1975-84 (Anon. 1987). Manitoba's harvest declined from about 35 000 to 28 000 over the same time period, with 50% and 60% higher harvests during the 1970's single-year and 4-year lows, respectively (annual data provided by D.I. McKay, pers. comm.).

In British Columbia, the 1980's single-year peak was 28% lower than that in the 1970's, while the cumulative total over the three highest years was 36% lower in the 1980's, thus the pattern and amplitude of difference is similar to that observed in Alberta. Over the 10-year periods described above for Manitoba and Saskatchewan, the B.C. harvest was down 16% (39 700 to 33 300), but that difference jumps to 32% (41 100 to 27 900) if started 2 years later to account for cycle phase differences. Although it is evident that B.C. experienced declining harvests similar to those in the other western provinces in the 1980's, those declines are not clearly related to harvest trends during cyclic lows. The lowest harvest in the 1970's (1119 animals) was only 10% higher than the single-year low in the 1960's, and was 14% lower than that in the 1950's. Cumulative harvests during the 4 low years in the 1960's and 1950's were 26% higher and 2% lower, respectively, than the 4-year low immediately preceding the 1980's harvest decline. Over the past six cycles in B.C., the relationship between harvests during lows and that during highs has been entirely positive, the highest highs preceded by the highest lows and the lowest highs by the lowest lows (Table 2-10). That result probably reflects temporal changes in the general level of interest in lynx trapping, but does not support a view of negative impact of harvesting at the cyclic low in B.C. It cannot refute that view either, since the absolute level of the harvest provides no clue about the number of animals still remaining in the population.

The low Canadian harvests in the 1930's through 1950's were thought to have reflected continuing low populations due to overharvesting at about the turn of the century (Butler 1942; De Vos and Matel 1952), and there has been some suggestion that the 1980's decline may be a case of history repeating itself (Todd 1985). Historic Hudson's Bay records show considerably higher harvest peaks in most late-19th century cycles than have occurred since (Van Zyll De Jong 1971; Todd 1985), but it would be difficult to demonstrate direct effects on harvest levels decades later. Comparisons of historic and recent harvest levels are also risky, particularly given the environmental and social changes that have occurred.

Table 2-10. Relationships between lynx harvest lows and highs in British Columbia, 1929-1987

Five-Year Lows[1]			Three-Year Highs[2]		
Years	No. Pelts Sold	Rank[3]	Years	No. Pelts Sold	Rank[4]
1929-33	8,769	4	1935-37	10,646	4
1939-43	6,555	5	1944-46	7,228	5
1948-52	5,225	6	1954-56	6,888	6
1957-61	12,002	1	1962-64	24,592	1
1967-71	11,447	2	1973-75	22,550	2
1976-80	9,922	3	1982-84	14,487	3

[1] Five-year lows: Figures under pelts sold are the sum of sales for the lowest year plus two years prior and two years after.

[2] Three-year highs: Figures under pelts sold are the sum of sales for the peak year plus one year before and after.

[3] Rank, from highest to lowest, in fur sales during five-year low periods.

[4] Rank, from highest to lowest, in fur sales during three-year high periods.

Whether or not the observed harvest patterns in the 1930's through 1950's were due to previous overharvest, there is some evidence that B.C. was relatively less affected than the prairie provinces. As shown in Fig. 4, the 1920's peak in B.C. was comparable to that in Alberta, and B.C. dominated the harvest at every stage of the cycle from then to at least the early 1950's. In contrast to the recent pattern, in which Alberta has often supplied 30% or more of the total Canadian harvest (Todd 1985; also, see Figure 2), B.C. led Alberta in 24 of 32 years through 1951, and produced 25% of the total Canadian harvest over that period. For the six major lynx-producing provinces, the 32-year totals, from data listed in De Vos and Matel (1952) were: B.C. - 76 073, Alberta - 68 913, Quebec - 57 388, Ontario - 44 548, Manitoba - 33 939, and Saskatchewan - 26 327. Comparable records for the Territories are not available, but the NWT and Yukon ranked 6th and 8th, respectively, among 10 lynx-producing jurisdictions in the early through mid-1970's (Table 2-9). Unlike other jurisdictions, both reportedly increased their harvests in the 1980's (9% and 27%, Todd 1985). Increased Territorial harvests could contribute to reduced peak harvests farther south, by reducing the extent of dispersal.

The comparisons given above suggest that B.C. may have a more stable harvest pattern than is the case on the prairies, especially Alberta. Other evidence includes the approximately 20-fold difference between peak and low Alberta harvests in the 1970's (Brand and Keith 1979), as compared with only an 8-fold difference in B.C. during that cycle (Table 2-8). Patterns of lynx population growth and exploitation in northeastern B.C. probably parallel those in adjacent northern Alberta. Thus, if B.C. is on the average more stable, most of the effect probably comes from the remaining, mostly mountainous lynx range in the province, where hare population fluctuations may be of lower amplitude and trapper access is more difficult.

Although the potential incentive effect of high pelt value seems clear (Section 2.6.1), the extent to which it actually influences harvest levels is not. De Vos and Matel (1952) described a negative relation between pelt price and the Canadian harvest in the 1920-1950 period, and that pattern also shows for recent years in B.C. (Fig. 5). The prices reflect the economic interplay between supply and demand, but the individual trapper in the woods can not know either of those with certainty. The catch precedes the sale, and the trapper can't really know how much effort he can afford to expend except in retrospect. A trapper doing well on marten would be happy to accept a $750 lynx as a bonus, but may not have the time to cut a mile of new trail to find it. A trapper doing poorly on everything else may not be able to afford to stay in the woods long enough to catch the lynx. Thus, high pelt price may be a more important factor in some areas than in others, depending on climate, habitat, access characteristics, and the abundance and value of other furbearers.

2.6.3 Harvest Management Considerations

British Columbia furbearers have recently been classified into three management categories in relation to individual home range sizes and differential vulnerability to harvesting (R. Archibald, pers. comm.):

Class 1 - Those furbearers present on Registered Traplines (RTL's) in manageable numbers (i.e., those for which harvest regimes can effectively be established by the trapper).

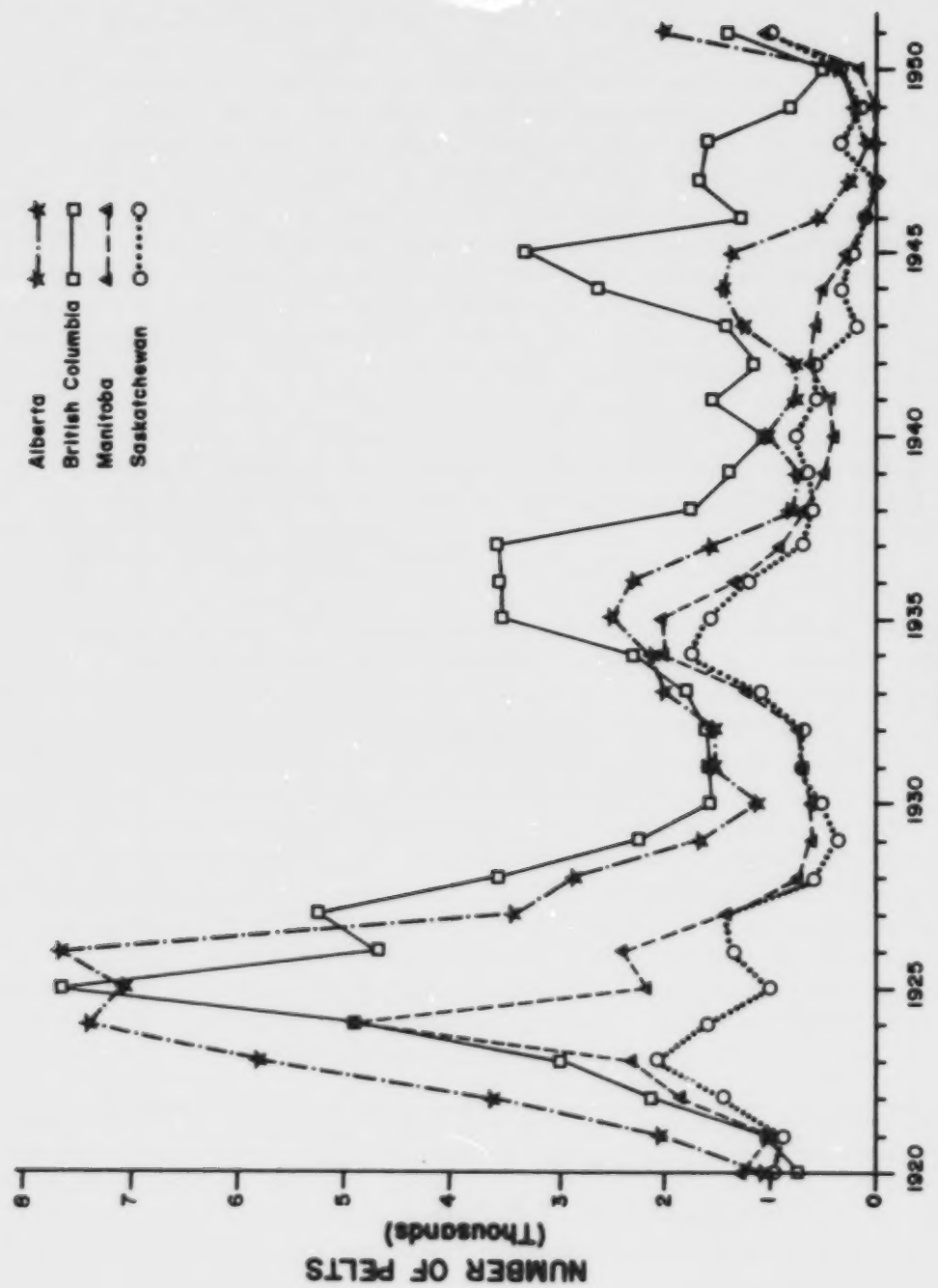


Figure 4. Lynx harvests in western Canada, 1920 - 1951.

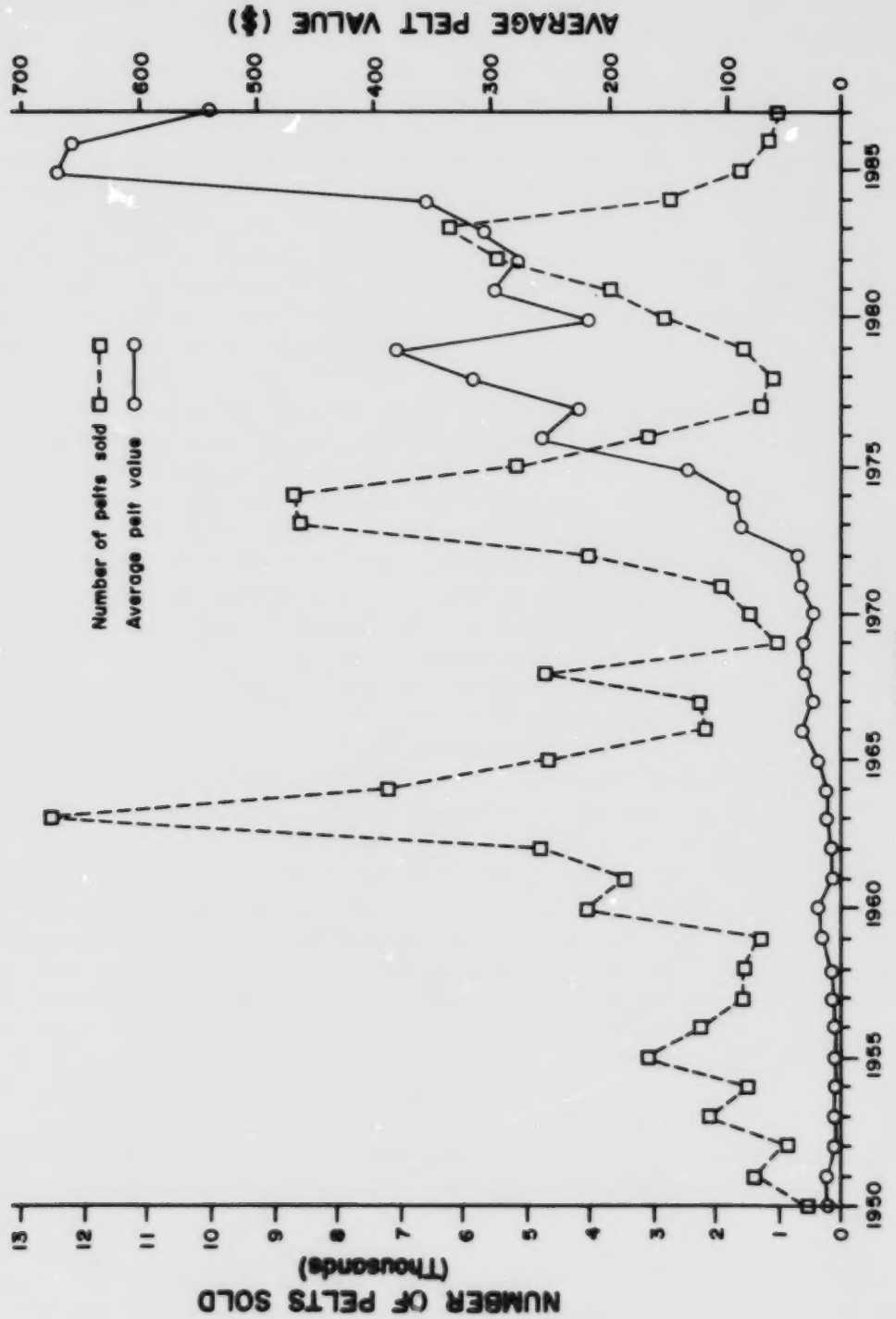


Figure 5. Lynx harvests and average pelt values in British Columbia, 1950 - 1987.

Class 2 - Those furbearers not present on (most) RTL's in manageable numbers, and which are vulnerable to overharvest.

Class 3 - Those furbearers not present on RTL's in manageable numbers, but not subject to overharvest (wolves and coyotes only).

Lynx are Class 2 species, and the stated management strategy is to apply harvest regulations (e.g., restrictive seasons and/or quotas) at the management unit or regional level.

For the 1987-88 year, the open season for lynx trapping was 3 months long (15 November - 15 February) over most of the province, with a longer season (4 months: 1 November - 28 February) in most management units north of 56° North latitude. No bag limits or quotas were in effect. An open lynx season for hunters, under a "small game" designation, ran concurrently with the above trapping seasons (bag limit of 1, compulsory inspection requirement). There has been no monitoring of hare or lynx populations, either by field indices or by questionnaire. The main harvest monitoring in the past has been at the pelt sales level, mostly involving only a province-wide tabulation of numbers. In recent years, trappers have been required to identify fur shipments and sales with assigned "Trapper Numbers", to enable compilation of harvest data by geographical units within the province, and monitoring of harvest age structure began in (1986-87??) with pelt measurements by (selected?) fur buyers.

Widespread harvest declines in the 1980's cycle, combined with current concerns about high pelt prices and increased harvest pressures, suggest the need for more intensive monitoring and harvest management. The following points summarize some major considerations for British Columbia in relation to research findings and management proposals and practices elsewhere:

A) *Constraints of the Cycle* - All available evidence indicates that lynx over most of their range are largely dependent upon snowshoe hares, and that lynx population levels generally follow those of hares in the 10- year cycle. There is some evidence that hare cycles are absent or of lower amplitude in southern portions of lynx range, possibly including much of southern B.C., although cyclic patterns of lynx abundance may still occur as a result of large scale dispersals following hare declines in other areas. Harvest trends over the years indicate that most of B.C. is influenced by, if not everywhere subject to, the 10-year cycle. It would appear that the only way to change population/harvest trends within a cycle would be to change hare population trends, and that is generally considered to be beyond management capability at this time (A. Todd, Alberta and R. Ward, Yukon, pers. comm.). Thus constrained by the cycle, simply assuming that populations will continue to increase until they start to decrease, and vice versa, managers are forced to think and operate in terms of 10-year blocks. The dilemma is that relatively few data points are produced over one professional career, and it is difficult and potentially risky to wait another 10 years to determine whether results from the current cycle truly represent a "trend".

B) *Biological Factors* - In relation to management, the major positive features of lynx life history and population dynamics are probably that they are capable of rapid population growth when conditions are right, do not seem to be subject to numerous natural mortality factors, and their mobility and dispersal tendencies reduce the likelihood of local extirpations in suitable habitat. Major negative features relate to the aforementioned dependency on the cyclic hare, especially

nutrition- related behavioral changes, declining condition, and poor recruitment when hares are scarce.

C) *Effect of Trapping* - It has been generalized that lynx are easily trapped, but there is abundant evidence that vulnerability to trapping varies among sex and age classes, and that physical condition related to nutrition might be a common underlying vulnerability factor within classes. Iurgenson (1955) believed that "...the trapping...yield is the result not of increase in the number of the species which is being procured but of a shortage of food." Thus, the effect of trapping probably varies with the stage of the hare cycle, and may range from low, if or when it is selective for the least secure (and probably least productive) individuals, to high if or when it is not.

D) *Harvest Versus Population Characteristics* - The apparent differential vulnerability between classes and/or in relation to condition, tending to favor survival of adults (especially females) and kittens, suggests that reproduction and composition data from harvest samples may often portray a pessimistic reflection of population performance. That is, things are probably never any worse and may often be better than the harvest data would indicate.

E) *Cycle Timing and Synchrony* - Detailed, long-term data from Alaska (O'Connor 1984), indicated that regional lynx populations peaked up to 3 years before harvest peaks, and that reproductive performance declined up to 4 years before harvests declined. Thus, harvest trend alone does not accurately reflect population performance and trend. Further, stages of the cycle varied by up to 2 years within three study areas whose total area approximates that of the Skeena Region, northwestern B.C.

F) *The Nature of Harvest Peaks and Lows* - A variety of evidence about the nature of lynx responses to local hare declines--increases in activity, movements, and home range size, cases of home range abandonment and long distance dispersals, deteriorating condition, reduced productivity and kitten survival, and at least some starvation-- are all consistent with a view that peak harvests may represent the period of greatest stress and relative trapping vulnerability of lynx populations rather than just a period of high numbers. The high peaks in the 1960's and 1970's, the largest in Canada in this century and resulting in use of epithets such as "invasion" and "irruption" to describe the unusual extent of lynx appearances in the northcentral United States (Adams 1962; Mech 1973; Gunderson 1978), presumably reflect attainment of higher numbers than in other cycles. However, they may also represent the highest mass vulnerability, with relatively fewer secure individuals because of temporary widespread social disruption and intraspecific competition for the declining food supply. Although peak harvests have a large potential for being compensatory at least in the short term, if they are less selective for particular sex and age classes, and occur in the post-reproductive period of the cycle, they may dramatically affect both numbers and composition of the population entering the low. The lowest harvests, on the other hand, may occur primarily after survivors of the sharp decline phase have dispersed and readjusted to the new, lower prey levels (Ward and Krebs 1985), and when many may again be relatively more secure.

G) *Harvest Objectives* - Due to the nature of the cycle, particularly as portrayed on graphs of harvest data, there is a tendency to consider the peaks as the focal point for increases. Unlike the case for most species, therefore, resulting management objectives may be directed to increasing rather than decreasing the amplitude of fluctuations--in effect, if successful, designing irruptions. Management of lynx may be sufficiently different that such an unusual approach is required.

However, given that commercial production of fur is the highest priority use for lynx in B.C., and in most other jurisdictions, preoccupation with maximizing total harvests, either at peak times or within portions of a cycle, may not be entirely appropriate. Consistent with a broader objective of maintaining viable populations throughout the occupied range, the ideal objective would maximize revenue (not pelts) per cycle, and would distribute it over the widest area, longest time, and among the most users. Although it has been suggested that increased peak harvests would result in proportional revenue increases (Todd 1985; Anon. 1987; Quinn and Parker 1988), such a result is not economically realistic unless some of the extra pelts produced during the higher peaks can be saved and sold in later years when the newly caught supply is lower.

H) *Accessibility* - As a rule, today's snowmobile, ATV, and occasional airplane-equipped trappers are more mobile than was the case in the first half of this century, and are capable of covering large areas in relatively short periods. However, some areas are much more accessible to mechanized travel than others, depending particularly on topography, forest cover, drainage, and extent of human developments such as road systems and exploration trails. In the heavily trapped Kenai, Alaska area, the range of mountains that was believed to serve as the main refugium for lynx in the area (Bailey *et al.* 1986) is smaller and closer to roads and population centers than are extensive mountainous areas throughout B.C.

I) *Dispersal* - As admonished by O'Connor (1984), dispersal to and from monitored areas is a potentially disruptive factor for management on a regional basis, and especially if it occurs mostly between trapping seasons, as found by Ward and Krebs (1985). The highest harvest peaks, such as in the 1970's, may result more from extensive mass movements of lynx from lightly trapped areas where hares have declined to more heavily trapped areas where they have not, rather than from local recruitment. For example, northern B.C. and the northern Prairies may occasionally receive heavy dispersal from the NWT and Yukon. Thus, management of lynx may be similar to management of waterfowl, with some jurisdictions benefitting from good reproduction and survival elsewhere, but not being able to do much about it.

J) *Interactions* - In most areas, the lynx is only one of several species that may be involved in local hare-predator cycles, and it may not be desirable to maximize lynx production, or possible to do so without also addressing management of the other species (see Dixon and Swift 1981). Lynx are apparently negatively affected by competition or social interaction with bobcats on Cape Breton Island, Nova Scotia (Parker *et al.* 1983), and increases in local competition among lynx and other hare predators such as coyotes, fishers, and certain raptors may reduce the local population potential for any one species.

K) *Other Factors* - As always, all available information must be tempered with a certain amount of "professional judgement". In some cases, factors such as the incentive value of high pelt prices in relation to accessibility and trapper density, may be the most important considerations.

2.6.4 Harvest Management Strategies

All accounts indicate that a "tracking strategy" is the most appropriate for lynx management, decreasing harvest pressure during the period of low population and recruitment and increasing it at some stage after population performance has improved. The major variation in current (1987-88) regulations and/or proposals in western North America, with hares apparently increasing but not

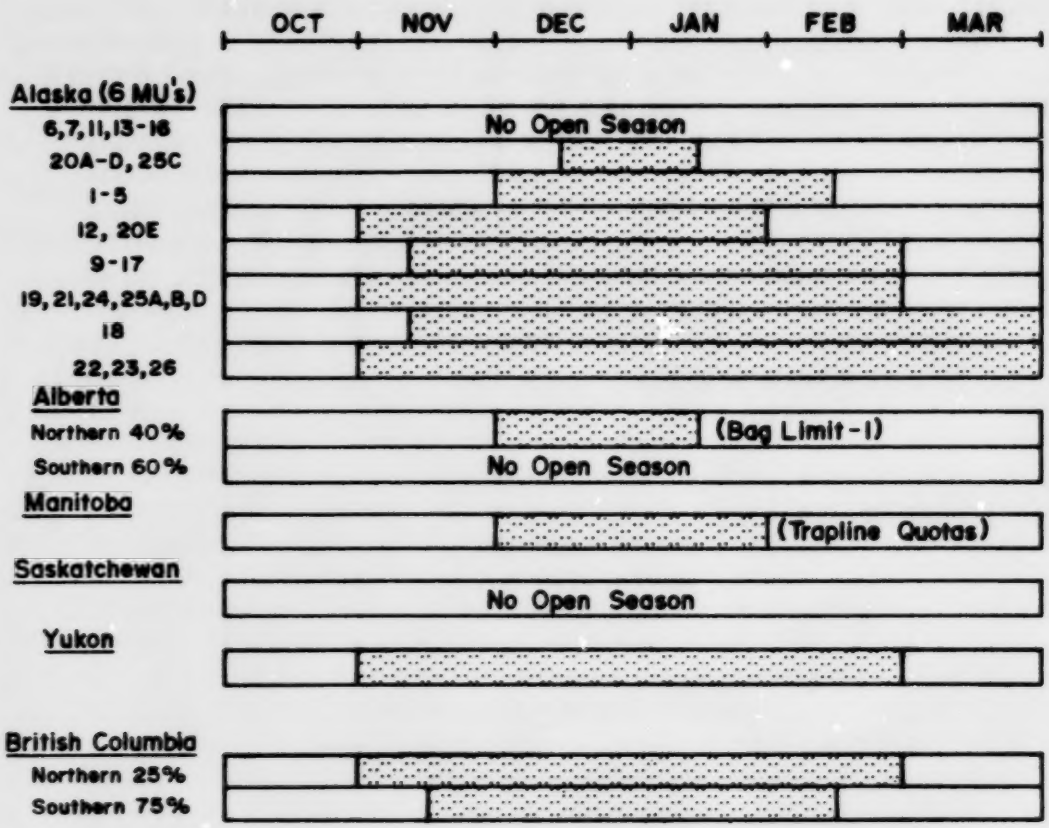
high in most areas, is in the degree of restrictions being applied--from shortened seasons to complete closures (Figure 6).

After detailed consideration of available options, manipulation of season length was judged to be the most appropriate method for regulating harvests in Alaska (ADFG 1987). Despite an open system in which anyone can trap wherever there is an open season, and therefore everyone can theoretically pursue and compete for the same lynx, the Alaska regulations remain relatively liberal. The single closure and seven different seasons proposed are based on harvest patterns, trapper numbers, availability of road access, remoteness from human population centers, hare population indices, and habitat quality. Some of their longest proposed seasons are in areas where cycles may not occur, but where "pulses of lynx" appear when Interior populations peak (ADFG 1987). To assist in interpretation of lynx population status, Alaska managers have been gathering data on the proportion of kittens in the harvest since 1977-78, and R.O. Stephenson (pers. comm.) is impressed with the degree of correlation between kitten occurrence and hare population indices. The Alaskans are also attempting to develop a technique for assessing lynx numbers in the field.

Until very recently, most Canadian jurisdictions have monitored lynx numbers primarily by comparing harvest trends between cycles (item "d", Section 2.6.2). Such comparisons are apparently the primary basis for current concerns about lynx population status in western Canada, and the conservative regulations presently in effect in the Prairie provinces (Fig. 6) reflect that concern. Present Yukon regulations, in place since 1984-85, represent a reduction by one month over those pertaining previously (month of March portion removed). In British Columbia, 1987-88 seasons were shortened by 2 weeks in most southern areas of the province, and by up to a month (2 weeks each end) in central and mid-northern areas.

Most seasons in all areas center on the December through January period of maximum pelt primeness. Because of apparent within-season differences in trapping vulnerability between sex and age classes, manipulation of seasons may change the composition of the harvest (Quinn and Parker, In Press). The only available data enabling description of the pattern within classes, from Nova Scotia during three years of hare decline (Parker *et al.* 1983), are shown at the bottom of Figure 6. The pattern for kittens, highest occurrence in later months, also occurred in Ontario during a period of population increase (Quinn and Thompson 1985). Both areas also showed the strongest representation of yearlings in the early part of the season. The pattern by sex is less clear. Females dominated the Nova Scotia sample in November and December, and males thereafter (extent of difference not given), while it appears that males dominated throughout the season in Ontario. Differences between the sexes within any given period probably relate at least partly to behavioral differences, while those between ages may largely reflect differences in nutritional security and condition factors (Section 2.4.6), the extent of which will vary at different stages of the cycle.

The primary management implications of within-season harvest composition changes are that a) managers may be able to select and/or protect certain classes by altering season dates, and b) harvest comparisons between areas and between years may not be valid if different seasons are involved. The latter seems particularly important in view of increasing attempts to monitor the kitten component of harvests concurrent with increasing conservatism in season length. Shortening seasons at the end may protect members of maternal family groups, but will decrease the ability to detect them in harvest samples.



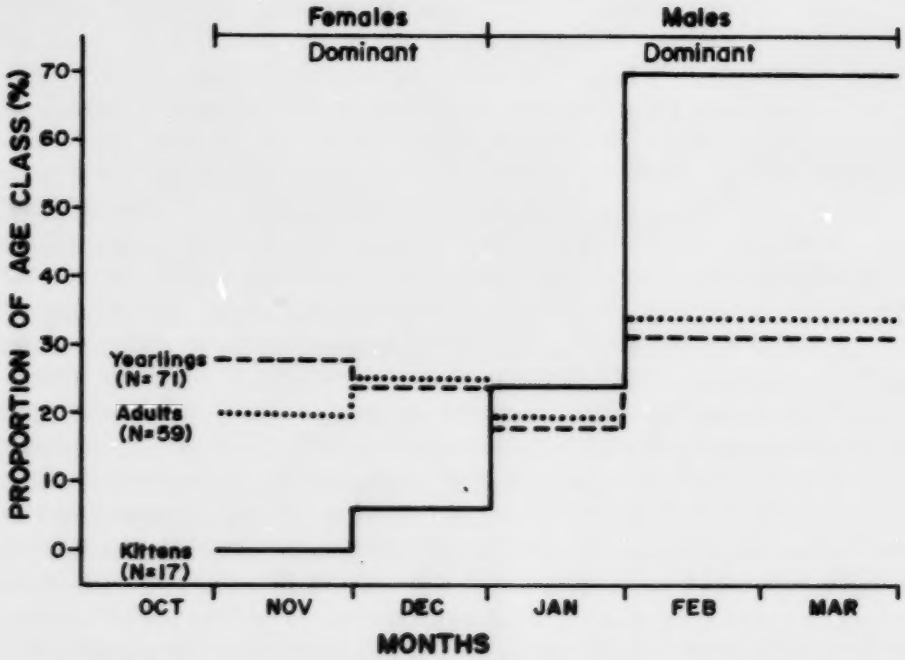


Figure 6. 1987-88 lynx trapping seasons (shaded) and special restrictions in western North America. Regulations shown for Alaska are as recommended in ADFG (1987). The graph for harvest age pattern is from data in Parker *et al.* (1983).

Bag limits and quotas at the low of the cycle can be effective over a large area if much of the harvest is normally taken by a small proportion of trappers. As described by W. Runge (pers. comm.), a quota of one lynx per trapper in Saskatchewan would theoretically allow a harvest of about 3000 lynx, when only about 600 are taken without the quota. Those numbers suggest an average harvest, per trapper, of 0.2 animals, therefore the lowest possible quota (one) appears too high. However, for example, if 300 of those lynx would otherwise be taken by 60 trappers (five each), a quota of two could reduce the harvest by up to 180 animals (30%). Conservative quotas during the low may also spread the resource among more users, may serve as a pre-season gauge for the individual trapper in determining how much effort to apply to lynx trapping, and may allow some harvest selectivity for particular sex and age classes (see below). The applicability of quotas to B.C. trappers probably depends upon yet to be determined harvest characteristics, particularly geographic distribution and average yield per trapper.

It is recognized that as long as a local trapping season remains open for other species, there is potential for some lynx being caught incidentally. Although some consideration has been given to "methods and means" regulations to restrict use of certain trap sets and lures during lynx closures (e.g., Bailey *et al.* 1986; ADFG 1987), such regulations are difficult to enforce. It seems likely that modification of trapping methods in relation to lynx seasons is better undertaken at the voluntary level, by trappers. In that context, the major role of methods considerations may be in enhancing selectivity. Exclusive use of padded jaw leg-hold traps, and frequent trap checking, offers the possibility of live-release of least wanted individuals (Quinn and Thompson 1987; Quinn and Parker, In Press). In particular, adult females produce the lowest value pelts (Quinn and Gardner 1984), but they may constitute the most important class, biologically. Selective release of parous females may enhance population productivity, particularly if individuals learn from the experience and are able to avoid traps longer into the future than would otherwise be the case.

Some traps or trap sets may also tend to be selective for particular sex and age classes. In Ontario, Quinn and Thompson (1985) compared harvest results for snared lynx to those caught in leg-hold traps. There was little difference by age, but the ratio of males to females was higher in leg-hold traps than in snares. They speculated a difference in habitat use between the sexes, suggesting that most snared lynx were caught in sets designed for foxes and, by implication, habitat overlap is greatest between foxes and male lynx. However, trappers elsewhere regularly use snares for lynx, and both snares and leg-hold traps can be used in a variety of different kinds of trap sets. Snares and traps set "blind" in hare trails or other travel routes are effective, and are probably the least selective. Conspicuous "cubby" sets, particularly those using bait, are probably more likely to miss animals that are wary and sufficiently well-fed that they can choose not to enter. Thus animals caught in such sets may tend to be the least secure--yearlings, kittens, adults in poor condition--in which case the resulting selectivity may also constitute the most compensatory trapping mortality. Most trappers learn that lynx that are ambivalent about entering a cubby or too closely approaching a flag or lure set, will often circle nearby and may nevertheless by caught in properly placed blind snares or traps. Such captures, again, are probably relatively unselective. More research on this subject is needed, but snares stay operative in a wider range of weather conditions, may tend to catch a higher proportion of adult females, and certainly preclude live- release, therefore voluntary limitation of their use during the cyclic low may be appropriate.

The extent of harvests by non-trappers under B.C. "small game" regulations is not clear, but it is likely that incidental shooting is not selective for any particular class of animal and that it is

largely additive mortality. Under a tracking harvest strategy, and particularly given the priority of commercial use, an unlimited entry open hunting season during the cyclic low is probably not justified.

2.6.5 Population and Harvest Monitoring

More intensive lynx management in British Columbia will require more intensive monitoring. Although harvest information is clearly limited in the degree to which it can be used to document population status, particularly when regulations are altering harvest patterns, it is nevertheless needed to better describe the extent and distribution of trapper demand and the biological characteristics of the supply at different stages of the cycle. Local (trapline) or regional harvest objectives, quotas, and production are probably better expressed on some area-based system, such as the "harvest density" of Quinn and Thompson (1987), than on absolute terms.

A complete review of specimen analysis procedures is not possible here, but a few generalities will be given. Although age classes have been assigned on the basis of legbone and skull ossification criteria, the most reliable results are from tooth samples. Young-of-the-year can be distinguished by incomplete closure of the apical foramen of a canine tooth, and older age classes by incremental lines in dental cementum. The most detailed procedural accounts are given in Brand and Keith (1979), O'Connor (1984), and Quinn and Thompson (1985). Although most tooth preparation techniques were formerly very time consuming, involving decalcification and staining, there is now a direct-sawing technique that enables processing of up to 100 teeth per day (Johnston and Watt 1981). Kittens may also be distinguished by pelt measurements (Quinn and Gardner 1984), and aspects of recruitment are now being measured by that technique in several areas including Alaska (R.O. Stephenson, pers. comm.), the Yukon (Slough 1986; Ward and Slough 1987), and B.C. However, R. Stardom (pers. comm.) indicated that there may have been some interpretive difficulties in a recent sample of pelts from Manitoba.

No studies of female reproductive tracts should be undertaken without consideration of the methods and recommendations of O'Connor (1984). Condition indices, which are important as they relate to recruitment and aspects of vulnerability to trapping, have been assessed by subjective evaluations or measurements of various fat deposits (Brand and Keith 1979; Parker *et al.* 1983; Stephenson 1986; Quinn and Thompson 1987), but a system that compares directly between areas and times has not yet been adopted.

It seems to be generally agreed that informed management requires measures of lynx population status in addition to harvest data. Information on distribution and indices of relative abundance in winter may be obtained by track counts, both ground and aerial (Legendre *et al.* 1978; Stephenson 1986; Ward and Slough 1987), and a density estimate, with confidence intervals, has been obtained by intensive snow-tracking and telemetry in the Kenai area (Schwartz and Becker 1987). Since lynx abundance and population performance is so closely tied to snowshoe hare population trends, monitoring of hare numbers is also recommended as an essential part of the lynx management data set (Quinn and Parker, In Press). Some of the references listed in Appendix A outline methods for detailed hare surveys. O'Connor (1984) found that lynx and hare abundance indices based on responses to annual trapper questionnaires were more reliable indicators of lynx population status in Alaska than were harvest data. Such questionnaires, now also used in the Yukon (Ward and

Slough 1987), may provide adequate trend information, particularly if augmented by local, more technical spot-checks.

2.7 HABITAT MANAGEMENT

The most neglected aspect of lynx biology and management to date involves consideration of the contribution of habitat factors to population levels. Local impacts, such as extensive flooding in association with hydro dams, are known to have population consequences, and a policy of compensation to trappers in flooded lynx habitat is in place (B.C. Hydro 1981). Agricultural clearing may also remove land from lynx production (Todd 1985), and it is generally thought that developments such as mineral exploration may negatively affect populations, by providing trappers and hunters new and often extensive access to former refugia. However, the largest potential for habitat-related impacts on lynx in British Columbia is in the forest industry, whose activities are dominant and widespread throughout the province.

As documented in Section 2.3.1, mature forest is used by lynx for natal denning and resting cover, while successional stages required by snowshoe hares are used for hunting. The required or optimum interspersion of those and other types is not known, but forestry clearly alters habitat features over large areas. New burns are of little value to hares or lynx, and may be negative (Bailey 1981), but appear to be the most productive of all habitats from about 15-50 years post-fire (Stephenson 1984c; Bailey *et al.* 1986). Widespread fire suppression by forestry interests reduces the proportion of available habitats in the stages most productive of hares and, therefore, must reduce the long-term abundance of lynx (Fox 1978; Stephenson 1984c; ADFG 1987). Forestry clearing has some potential for mitigating fire habitat losses, but extensive clearcuts are considered "unacceptable" (Quinn and Parker, In Press). Even with smaller cutblocks, silvicultural practices such as manual or herbicidal "brush control" and commercial thinning may reduce habitat suitability for hares and lynx, and reduced hare attractiveness may be part of the silvicultural objective to prevent depredations on conifer regeneration (Nellis 1971).

Parker *et al.* (1983) indicated that it was too late to integrate forestry and lynx management on the highlands of Cape Breton Island, Nova Scotia, but that prescriptions such as reduced size of clearcuts and interspersion of uneven-aged cuts and mature conifer stands would have been desirable. It is probably not too late in much of northern British Columbia, but it is certainly about time.

2.8 RECOMMENDATIONS

Given present knowledge about the biology of lynx and the nature of lynx harvests, and assuming continued high demand for lynx fur, the following management measures are recommended for British Columbia.

To Provincial Managers

1) Harvest Management - The major recommendation is for adoption of a tracking strategy, taking action to reduce harvests during the cyclic low in numbers and recruitment, and to increase them when population performance improves. Specific components are as follows:

- Effective in the 1988-89 trapping season, further reduce season length in northern Management Units, to conform to that in the rest of the province (3 months, 15 November - 15 February). The most significant population growth and expansion potential is probably in the northern quarter of the province, and a more liberal season there could retard that potential. Further, uniform seasons will facilitate comparison and interpretation of harvest data, and allow better description of regional lynx populations and harvest characteristics throughout the province, to enhance future management.

- Maintain the existing season through at least the peak and decline phase of the present cycle, closely monitoring harvest results as outlined below. Populations are now (late 1987-88 trapping season) believed to be in the early increase phase of the cycle.

- Effective in the 1994-95 season (2 years after the next expected provincial harvest peak), establish trapline quotas based on harvest characteristics and objectives at that time. Such quotas will enable continued, but well- distributed and controlled harvests during the cyclic low.

- Thereafter, subject to future review, regulate harvests primarily by increasing or decreasing quotas, in reference to measures of population status.

2) Harvest and Population Monitoring - The tracking strategy can be fairly and effectively employed only if population performance and status are monitored. It is important to understand that population peaks and trends may precede harvest peaks and trends by 1-2 years over most of the province. Recommended data gathering vehicles and activities are as follows:

- Continued compilation of lynx harvests, by trapline, to enable description of harvest density and distribution at different stages of the cycle.

- Continued pelt examinations/measurements, to determine the kitten component of the harvest, by area and stage of cycle.

- Analysis of carcass samples (age, sex, productivity) and detailed harvest data (dates, methods) from selected trappers.

- Administration of annual trapper questionnaire: Based on observations of tracks and sign, and in reference to the previous trapping season, trappers to indicate trends (increasing, decreasing, stable) for snowshoe hare, lynx, and other selected furbearer and prey species.

- Selected snowshoe hare trend surveys to correlate with questionnaire results.

3) Habitat Management - Although precise habitat protection requirements and enhancement possibilities for lynx are not yet known, forest management practices are paramount among

concerns in British Columbia. Population management objectives cannot be met without a suitable interspersion of a) "mature" forest for cover and denning, and b) earlier seral habitats that support snowshoe hares and thereby provide the nutritional basis for lynx population growth and expansion. Forestry matters that need to be addressed in relation to lynx management include, but may not be limited to, the following:

- Fire suppression as related to timber values and hare population potential.

- The compatibility, by vegetation zone or region, of hare habitat enhancement and forestry/silviculture objectives.

- Cutblock size and juxtaposition with adjacent habitats.

- Silvicultural treatments that may affect hare production.

To Trappers

Although the lynx is to be managed as a Class 2 species in British Columbia, with its harvest designed and administered primarily by provincial authority, intensive management at that level cannot succeed without the full cooperation and support from trappers in complying with regulations and providing required samples and information. Trappers may also be able to assist in local enhancement of lynx populations by certain voluntary actions, particularly at the low of the cycle (when quotas are in place), as follows:

- Avoid expanding trapping operations to remote hare/lynx "refugia" (small local pockets of hares) on your trapline. Lynx that can maintain stable home ranges and survive the low in such areas are the capital that later population expansion will build upon.

- Consider live-release of unhurt adult females. They are probably the most valuable animals biologically, but are usually the least valuable for fur.

- Minimize the use of trap and snare sets that may take even the wariest animal; rather, concentrate on use of sets, particularly baited cubbies, that may take mostly young, foolish, and/or nutritionally poor animals that would be the least likely to survive anyway.

- Practice enhancement of local hare habitats such as subalpine or streamside willow patches by cutting stems that have grown beyond normal winter use by hares.

- Intensify trapping effort on local furbearers that may compete with lynx for hares, particularly coyotes in many areas.

- Keep informed about habitat developments on and near traplines and, with fellow local trappers, interact with appropriate agencies to insure lynx and hare values are considered.

To Administrators and Researchers

Fully informed lynx management will require more knowledge than is presently available. Solid, ongoing research projects on aspects of population management are presently underway in Alaska and the Yukon, and additional studies on such topics may be redundant. The most pressing needs in British Columbia at this time are for a better understanding of snowshoe hare distribution, biology, and cycle patterns in the diverse ecological zones of the province, and of habitat requirements and relationships for both hares and lynx in those areas. Data on the nature and extent of lynx occurrence in particular areas, i.e., whether due mostly to immigration or local reproduction, may be determinable from harvest samples, but separate research will be required for hares.

Trapper education programs should be updated to include rationale and instructions on a) providing reliable harvest data and questionnaire responses, b) aspects of habitat protection and enhancement, and c) voluntary procedures such as identification and live-release of adult female lynx.

* * * * *

PART 3: LITERATURE ON LYNX
An Annotated Bibliography

3.1 INTRODUCTION

The following bibliography serves as the raw material from which most of the information and ideas presented in Parts 1 and 2 were drawn. The ideal objective was to compile a "complete" list of papers on the biology and management of *Felis lynx*. That objective will not have been fully realized, particularly for the European form and for the more specialized biological disciplines, such as physiology and morphology, that may not deal with the whole animal. In addition, I have not consulted popular periodicals or books, assuming that most information presented on lynx in those sources has been summarized from the scientific literature. It is possible that some useful observations at the layperson level have therefore been missed. It was also impractical to examine all of the general sources dealing with faunal lists and species status at the regional (usually provincial or state) level, although some may contain important information on the nature, extent, and timing of lynx occurrences, particularly in relation to local "irruptions' corresponding to post-decline dispersal. Finally, in the time available for this compilation I was not able to obtain copies of all papers that my literature search suggested might be of interest; most of those are nevertheless listed here and are identified as "not seen".

Those caveats aside, I am confident that I have located all of the major published North American papers that relate directly, and most that can be considered to relate indirectly, to management of the species. However, it is apparent the interest in lynx research and management has peaked within the past decade and there are probably ongoing projects that I have not been made aware of, and recently completed graduate theses that I haven't heard about. As always, the chore of keeping abreast of the literature is critically important, frustratingly time-consuming, and endless.

A secondary objective for this bibliography was to provide sufficient information for each entry so that the reader could A) readily understand the nature, scope, and specific conclusions relative to management, and B) confirm whether a particular paper required additional study. This section, then is to serve both as a summary and a "filter", hopefully reducing the need for duplication of library research effort and allowing more time for consideration of and action on lynx management problems.

3.2 FORMAT

Each item in the following pages consists of a complete bibliographic citation, followed by a 3-digit identification number. Most, except for a few that were not seen, also include a series of three descriptive elements A, B, and C, defined as follows:

A) *Management Significance* - My subjective assessment of the paper's relative importance in a management context (scale of 0-3, corresponding to nil, low, medium, and high). Note that all papers on population dynamics subjects and/or all from British Columbia were considered to be at least "low" (=1) significance.

B) *Geographical Location* - Broad location of study area and/or primary data source(s), usually a province, territory, state, or country, but the following designations are also given: a) Holarctic (study pertinent to whole circumpolar range of the species, b) North America (range of *F. l. canadensis*). c) Mackenzie (historic fur region in northern Canada) and d) General (no particular location(s) pertain).

C) *Nature and Extent of Study* - Methods, timing, sample sizes and duration.

Following the above elements are lists of keywords, under the following broad headings: Description, Habitat Characteristics, Life History, Population Dynamics, Species Management, Habitat Management, and Other Topics. Together with the identification numbers, the headings, and keywords are primarily to facilitate indexing and summarization. Table 3-1 lists and briefly defines the keywords used. It is acknowledged that the reader may have a different perception of the arrangement and degree to which particular topics should be covered in this list. The objective was for the list to be as thorough as possible, without being cumbersome. During preparation of the bibliography, some of my original keywords were split into two or more when it became evident that the extent of the study warranted it, while others were lumped into larger categories because of relatively little coverage. The overall objective was to emphasize topics with clear management implications and/or applications. The rationale for considering particular topics as "management" material is given under corresponding headings in the narrative section on considerations for lynx management (Part 2).

The final and often longest entry under each bibliographic item, entitled "Comments", consists of statements summarizing management-related contents in detail. Again, there is a judgemental aspect to material included--I have attempted to be faithful to each author's material and interpretations, and have neither evaluated nor critiqued. For consistency, all findings are presented in the past tense, although some are clearly more "past", i.e., tending toward obsolete, than are others.

TABLE 3-1. LYNX BIBLIOGRAPHY: SUBJECT HEADINGS AND KEYWORDS

DESCRIPTION
- features (physical form, size, variations)
- taxonomy
- distribution (including "unusual" occurrences)

HABITAT CHARACTERISTICS
- study/area (general description)
- vegetation (broad habitat classifications)
- cover (vegetation types as related to particular activities)
- climate (seasons, temperature, precipitation as factors relevant to populations)

LIFE HISTORY
- lifehist (general, covering all or most aspects)
- food (food habits, broad or seasonal)
- nutrition (aspects of metabolism and growth)
- activity (daily and/or seasonal patterns)
- hmrange (home range)
- movements (daily and/or short term)
- dispersal (including immigration and emigration)
- socbehav (social behavior, territoriality)
- behavior (other than social behavior, e.g. foraging)
- health (condition, parasites, diseases)
- denning (characteristics/use of dens, beds, nests)
- pelage (fur characteristics, moult patterns, pelt primeness)

POPULATION DYNAMICS
- cycles (periodic population fluctuations)
- natality (fecundity, productivity, reproductive biology)
- mortality (documentation of causes and/or rates)
- poptrend (population numbers, densities, indices)
- popcomp (sex and/or age composition)
- popreg (population regulation, limiting factors)

SPECIES MANAGEMENT
- census (methods for assessing numbers, trends, indices)
- age/tech (determination of specimen ages)
- gen/tech (field study methods, including capture, handling, marking, telemetry)
- kill/tech (methods of collecting and analyzing harvest data)
- repro (methods of assessing productivity, from specimens)
- economics (fur and/or ecological value, depredations)
- harvest (nature, extent, and/or effects)
- interactions (relationships with other species)
- harv/strategy (harvest options, recommendations, regulations)
- transplants (introductions to new or formerly occupied range)
- refuges (parks, management areas)

HABITAT MANAGEMENT
- fire (effects of wildfire and associated succession)
- other/nat (effects of other natural forces--e.g. flood, insect damage)
- forestry (effects of logging and silvicultural treatments, and associated succession)
- other/impacts (effects of human developments other than forestry: agricultural alienation, access, dams...)
- hab/strategy (recommendations, prescriptions)

OTHER TOPICS - mostly little or no perceived direct significance for management, e.g., history, bibliography, paleontology, zoogeography, physiology, morphology, genetics, evolution, embryology.

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3.3 LYNX BIBLIOGRAPHY

Adams, A.W. 1963. The lynx explosion. N. Dakota Outdoors 26: 20-24.

001 A) 1: B) North Dakota; C) Compilation of specimen and sighting records.
Description - distribution
Life History - dispersal
Population Dynamics - poptrends
Comments - since about 1900, an occurrence of a lynx in North Dakota has been a rare event--about one certain record every 3-4 years; due to what was interpreted as primarily an influx from Canada, lynx became very abundant in the northern part of the state in 1962, with an estimated 200 shot or trapped; one trapper with 45 years experience caught 39 animals in an area where he never caught one previously.

Adams, J.R. 1966. Taenids from *Lynx* in British Columbia with a comment on *Taenia monostephanos* von Linstow and other taenids with a single crown of hooks. Pages 480-481 *in* A. Corradetti (ed.). Proc. First Internat. Congr. Parasitol., Pergamon Press, Oxford.

002 A) 0; B) British Columbia; C) Examination of the parasites only.
Life History - health.
Comments - Both lynx and bobcat yielded taenids, but source locations and numbers of cats involved, and infection rates, are not mentioned.

ADFG. 1987. Report to the Board of Game on lynx management. Alaska Dep. Fish and Game, Div. of Game, Juneau. 30pp. (Provided by R.O. Stephenson).

003 *Description* - distribution
Habitat Characteristics - vegetation, cover.
Life History - lifehist.
Population Dynamics - poptrend.
Species Management - harvest, harv/strategy.
Habitat Management - fire, other/impacts.
Comments - This is an excellent review of the social, economic, and biological aspects that combine to create the current concern for lynx management throughout the species' North American range--failure of the law of diminishing returns because of high pelt prices, hence continued trapping pressure during cyclic lows, is a major contributor to the problem as it exists in the 1980's; as elsewhere, lynx are generally cyclic in Alaska, following the hare cycle by 1-2 years, but the cycle is not in synchrony statewide; as elsewhere, peak harvest during the early 1980's was less than in 1960's and 1970's. although that may not be due entirely to effects of trapping mortality--there is evidence of lower hare peaks in the 1980's in at least some areas; other relevant changes in Alaska in recent decades include a declining economy (making high lynx pelt prices increasingly attractive as a source of income supplement), increases both in general population and in the number of trappers, improved access through expanded networks of roads and increased use of snowmobiles and ATV's, and increasingly effective forest fire suppression; the two broad habitats of greatest importance to lynx are 1) "mid-successional vegetation stages" in large expanses of mixed forest "...in which fore governs habitat diversity..." and 2) alpine shrub thickets near

timberline where "...snowshoe hare and other small game populations appear to be either not cyclic or not in phase with cycles in forested lowlands, thus providing lynx with food during periods of food scarcity elsewhere..."; the pros and cons of several different harvest management options are discussed--it is concluded that the presently most practical strategy is manipulation of seasons rather than methods and means, bag limits, or quotas: a tracking strategy, with greatest restrictions when lynx populations and recruitment are low, is recommended, but leaving at least some opportunity for harvest at that time in all but the most accessible units; parameters to be monitored in relation to the setting of regulations include trapping pressure, percentage of kittens in the harvest, and measures of levels and trends of lynx and hare populations; current lynx regulations and management strategies in Canadian jurisdictions are briefly reviewed, for perspective.

Anon. 1987. Wild fur fact sheet: lynx management. Unpubl. Information Leaflet, Fur Div., Saskatchewan Parks, Recreation, and Culture, Prince Albert. 1p. (provided by Wayne Runge).

004 A) 2; B) Saskatchewan; C) Summary of management rationale and strategy.
Population Dynamics - poptrend.
Species Management - economics, harvest, harv/strategy.
Comments - It is noted that high numbers of lynx were harvested in the province in peak years of 1959, 1969, and 1977, but numbers had since declined to a low in 1985; during the 1965-74 cycle, the total harvest was 43 000 animals, while only 22 000 were taken 1975-84; based on the above trends, the trapping season for lynx was closed in 1987-88.

Archibald, H.L. 1977. Is the 10-year wildlife cycle induced by a lunar cycle. Wildl. Soc. Bull. 5: 126-129.

005 A) 1; B) Canada; C) Correlation of peaks in lynx fur returns (Hudson's Bay records, 1820's through early 1900's).
Population Dynamics - cycles.
Other Topics - history.
Comments - An interesting attempt to explain the periodicity of the 10-year (lynx, hare, grouse) cycle, but with no clear management implications.

Arditi, R. 1979. Relation of the Canadian lynx cycle to a combination of weather variables: a stepwise multiple regression analysis. Oecologia 41: 219-233.

006 A) 1; B) Mackenzie; C) Analysis of historic harvest data, 1821-1934.
Habitat Characteristics - climate.
Population Dynamics - cycles.
Comments - Notes that all studies indicate that the lynx cycle is a consequence of the hare cycle, but that the hare cycle is yet to be explained; this study relates combinations of climatic factors to lynx harvest returns, believed to be the best available indicator of hare population trends, to try to explain the hare cycle; the analyses suggest that unusual precipitation and temperature patterns in the transition periods spring-summer and fall-winter, acting on juvenile hare survival. amy be particularly important.

B.C. Hydro. 1981. British Columbia Hydro and Power Authority, Registered Trapline Program. 24pp.

007 A) 2; B) British Columbia; C) Considerations for compensating trappers whose traplines are affected by hydro developments.
Species Management - harv/strategy.
Habitat Management - other/impacts, hab/strategy.
Comments - Supporting data and habitat definitions are not given in this document, but reasonable harvest densities (number of lynx/km^2) at lows and highs in the cycle, and in poor, moderate, and good habitats, respectively, are listed at 0.003-0.0008, 0.009-0.02, and 0.018-0.05.

Bailey, T.N. 1981. Factors influencing furbearer populations and harvest on the Kenai National Moose Range, Alaska. Pages 249-272 *in* J.A. Chapman and D. Pursley (eds.). Worldwide furbearer conference proceedings, Aug. 3-11, 1980, Frostburg, Maryland.

008 *Population Dynamics* - poptrend.
Species Management - harvest, harv/strategy.
Habitat Management - fire.
Comments - It is speculated that wildfires on the refuge may have caused declines in lynx numbers initially, but resulted in long-term gains through benefits to snowshoe hares; increasing harvest pressure on lynx during the low in the cycle is documented; a "tracking" harvest strategy, possibly monitored by population indices of snowshoe hares, is recommended.

Bailey, T.N., and E.E. Bangs. 1983. The significance of natural sanctuaries in maintaining lynx population levels on the Kenai National Wildlife Refuge. *In* S.W. Buskirk (ed.). Abstracts of Pap. Pres., Third Northern Furbearer Conf., 22-23 March 1983, Univ. of Alaska, Fairbanks.

009 A) 3; B) Alaska; C) Radio-tracking and analysis of harvest data.
Population Dynamics - poptrend.
Species Management - harvest.
Comments - Abstract only: most of the biological investigations suggested in this preliminary report were expanded and results presented in subsequent papers, summarized below; an important point here is that most lynx were being caught in remote rather than accessible areas during the population low of the early 1980's, suggesting that "...naturally well-protected areas, or sanctuaries, are significant in maintaining the refuge's lynx populations" by supporting core populations that provide dispersing animals to the accessible, more heavily trapped areas.

Bailey, T.N., E.E. Bangs, M. R. Portner, J.C. Malloy, and R.J. McAvinchey. 1986. An apparent overexploited lynx population on the Kenai Peninsula, Alaska. J. Wildl. Manage. 50: 279-289.

010 A) 3; B) Alaska; C) Radio-tracking 12 animals, assessment of hare densities, and examination of carcasses from trappers.

Habitat Characteristics - study/area, vegetation.
Life History - hmrange, movements.
Population Dynamics - natality, mortality, poptrend, popcomp.
Species Management - economics, harvest, harv/strategy.
Habitat Management - fire.
Comments - In response to increasing pelt prices, and with long (4 to 4.5 months) seasons and no limitations on numbers or distribution of trappers and trapping pressure, lynx were apparently overexploited on the Kenai National Wildlife Refuge (KNWR) in the 1970's; the harvest in 1971-74 (572) was almost 6-fold larger than that in 1981-84 (99), despite a more than 60% increase in number of documented trappers in the early 1980's; most lynx taken in the late 1970's and early 1980's were in less accessible and lower quality habitat, and with lower trapping effort; although two old males, aged 10 and 12 years, were taken from relatively remote areas, the average age of trapped animals ranged from 1.9 (30 males) to 2.3 (31 females); mortality of radio-collared animals increased from 44% to 86% between 1982-83 and 1983-84, and was 90% over the 2 year period; the dramatically lower amplitude lynx cycle, as telemetry and snow tracking studies, occurred despite an increase of hares to estimated local densities of over 1000/km² in 1983 and 1984; based on observed trapping mortality of the radio-collared animals, juveniles were 5 times as vulnerable to trapping as adults, and males were twice as vulnerable as females; following continued harvest during the cyclic low, estimated densities of lynx on the KNWR during the increase and high phases of the hare cycle in the late 1970's and early 1980's (1.0/100 km² overall, and up to 2.3/100 km² in the highest quality habitat) were comparable to those documented during hare lows elsewhere; highest snowshoe hare use and apparent densities were in a 1947 burn, followed by alder-dominated and 1969-burned habitats, while mature forests showed the lowest use; despite high prey abundance, lynx home ranges were fairly large (50 and 89 km² for two females with young, and 64 and 783 km² for two adult males--on average the female ranges were less in summer (25 km²) than in winter (49 km²); continued increase in pelt prices insure continued interest in harvesting lynx--in 1984-85 the most accessible (northern) region of the KNWR was closed to lynx trapping by emergency order, the lynx season throughout the Kenai Peninsula was reduced from 120 to 47 days, and to reduce the incidence of "accidental" catches, cubby, bait, and flag sets commonly used for other species were prohibited in both the lynx closure area and in other areas during the closed season.

Bailey, T.N., E.E. Bangs, M.F. Portner, T.V. Schumacher, and M.B. Kesterson. 1987. Response of lynx to management changes on the Kenai National Wildlife Refuge, Alaska, 1984-87. *In* B. Townsend (ed.). Abstracts of Pap. Pres., Fourth Northern Furbearer Conference, 3-4 April 1987, Alaska Dep. Fish and Game, Juneau.

011 A) 3; B) Alaska; C) Radio-tracking, 22 lynx, March 1984-February 1987.
Population Dynamics - mortality, poptrend.
Species Management - harv/strategy.
Comments - Abstract only: This study compared results for 13 lynx in an area closed to trapping, and 9 in an area with an open, but reduced season; 8 of 10 mortalities were from trapping, 1 from vehicle collision, and 1 unknown; mortality was reduced and local population density appeared to be increasing in the closed area, while mortality was greater and density apparently decreasing in the open area.

Balis, M., and I. Chudlik. 1970. THe effect of the lynx (*Lynx lynx*) on the seasonal changes in density of red deer, roe deer, and chamois populations in the area of the Tatra National Park. Lynx 11:118-123.

012 *Comments* - not seen: listed in Sweeney (1977).

Barash, D.P. 1971. Cooperative hunting in the lynx. J. Mammal. 52: 480.

013 A) 1; B) Montana; C) Incidental observation.
Life History - food, behavior.
Comments - Three lynx, interpreted as two adults and 1 juvenile, apparently cooperated in catching and eating a ground squirrel.

Bergerud, A.T. 1971. The population dynamics of the Newfoundland caribou. Wildl. Monogr. 25. 55pp.

014 A) 2; B) Newfoundland; C) Long-term (10-year) study of caribou.
Life History - food.
Species Management - economics, harv/strategy.
Comments - It was concluded that lynx predation on newborn calves was "...the primary limiting factor..." in two major caribou herds, occurring primarily during lows in the snowshoe hare cycle.

Berrie, P.M. 1972. Sex differences in response to phencycladine hydrochloride in lynx. J. Wildl. Manage. 36: 994-996.

015 A) 2; B) Alaska; C) Capture/handling phase of field study.
Species Management - field/tech.
Comments - Males were immobilized almost twice as long as females by a given dose of the drug, although long-term detrimental effects were not evident.

Berrie, P.M. 1974. Ecology and status of the lynx in interior Alaska. Pages 4-41 *in* R.L. Eaton (ed.). The world's cats. Vol. 1. World Wildl. Safari, Winston, Oregon.

016 A) 2; B) Alaska; C) Radio-tracking, analysis of harvest records, necropsy of 3428 specimens obtained from trappers 1964-1970, trapper questionnaires, and trapper interviews.
Habitat Characteristics - study/area, vegetation.
Life History - hmrange, movements, denning.
Population Dynamics - natality, poptrend.
Species Management - field/tech, harvest, harv/strategy.
Comments - Home ranges of 14 to 25 km^2 were documented, although monitoring effort was not consistently applied; three apparent natal dens were found, two in spruce blow-down situations and one in "a tangle of washed up spruce roots" beside a creek--the last containing 5 kittens whose eyes had not yet fully opened (4 July 1970); in the harvest, as determined from carcasses purchased from trappers, males outnumbered females (about 60:40) in 2 of 3 years; the author postulated differential vulnerability of the sexes to trapping, but with seasonal differences-- his live-trapping efforts in summer netted 13

females and 1 male, while those in winter caught 1 female and 6 males; mean numbers of placental scars generally decreased from 1964-65 (5.01) through 1969-70 (3.60), but kits and yearlings increased in the harvest in the later years, especially in 1969-70; hares were believed at the low or slightly increasing at the start of the study period, and lynx were declining through 1966-67 and increasing thereafter; it is concluded that lynx survive primarily on small, local concentrations of hares during the low of the hare cycle, and that increased hunger and hunting activity at that time makes them more vulnerable to trapping; it is postulated that trapping during the low could result in a progressive decline in the cyclic amplitude, and a lynx trapping closure for up to 3 years during that time is recommended; it is noted that increase of human developments providing roads into wilderness areas, plus the advent of ATV's and snowmobiles, have greatly increased access for trappers to lynx refuge areas.

Birkeland, K.H., and S. Myrberget. 1980. The diet of the lynx in Norway. Fauna Norway Ser. A-1: 24-28.

017 *Comments* - not seen; cited in Stephenson (1986).

Brand, C.J., and L.B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. J. Wildl. Manage. 43: 827-849.

018 A) 3; B) Alberta; C) Necropsy of 1108 carcasses, 1971/72 -1975/76.
Life History - food, nutrition, health.
Population Dynamics - natality, mortality, poptrend, popcomp, cycles.
Species Management - field/tech, economics, harvest, harv/strategy.
Comments - During the study period, hares declined on the Rochester study area from 388 to 5/100 ha, lynx on the study area declined from 13 to 0, and Alberta lynx fur sales declined 12.5-fold; frequency of hare occurrence in stomachs decreased from 90% to 35% over the study period, while hare biomass declined from 97% to 65%--most alternative prey increased concurrent with lower hare consumption rates, but mice and voles comprised the only prey group whose frequency of use increased significantly (from 4% to 28%); increase in biomass due to increased use of mice and voles was negligible; indices of condition based on incidence of body fat indicated that trapped adults were usually in better condition than yearlings, that males were fatter than females, and that condition of all classes was poorest in late winters of low hare abundance; all reproductive parameters (ovulation and pregnancy rates and litter size as interpreted from placental scars) decreased as hares became scarcer; the sex ratio of the trapped sample was 48:52 in favor of females (n=974), but there were no significant sex differences within any age class or at different hare densities; mean age of the trapped sample rose from 1.6 years in 1971-72 to 3.6 years in 1975-76, as the proportion of kittens and yearlings decreased--however, there was evidence that kittens were under-represented in the sample, possibly because of care/protection provided by the adult female during the first winter; nevertheless, the estimated proportion of kittens in the population decreased from 66% to 3% between years of hare abundance and scarcity; estimated non-trapping mortality rates changed from 54-68% in 4 of 5 years (1965-67 and 1972-74), but was 34% in 1974-75--those rates and differences were not clearly related to spring population size; estimated trapping mortality averaged 10% of fall populations in 1965-67, but was 26% in 1971-75 (at similar population levels)--the

difference is speculated to have been due to higher pelt prices during the 1970's; within cycles, trapping mortality was density dependent (i.e., higher at higher population levels, and it appeared that trapping and non-trapping mortality were largely additive rather than compensatory; a "tracking" harvest strategy, with closures for about 3 years during the period of low/nil recruitment, is recommended; models of population increase under different management regimes show that the estimated Alberta population in the 1970's might have produced as many as 16 700 additional pelts (a 40% increase), despite 3 years of closure under a tracking strategy.

Brand, C.J., L. B. Keith, and C.A. Fischer. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. J. Wildl. Manage. 40: 416-428.

019 A) 3; B) Alberta; C) Snow-tracking, 1964-68 and 1971-75.
Habitat Characteristics - study/area.
Life History - food, nutrition, activity, hmrange, socbehav, movements, health, behavior.
Population Dynamics - natality, poptrend, cycles.
Species Management - census.
Comments - Lynx densities were related to hare abundance, with a 1-year lag in population trends--numbers on the 130 km² Rochester study area ranged from 3 in 1966-67 (2.3/100 km²) to 13 in 1971-72 (10.0/km²); there were no kittens in the study area population in 1964-67 and in 1973-75, when hare densities were 137/100 ha or less, but there were 6, 7, and 4 kittens in 1967-68, 1971-72, and 1972-73, when hare densities were 185, 499, and 200/100 ha, respectively; home ranges of adults varied from 11.1 to 49.5 km², and range differences did not appear to be related to either lynx or hare density; two females with kittens had smaller ranges (mean 17.8 km²) than did six lone adults (31.5 km²); home ranges overlapped, thus the lynx did not appear to be strictly territorial, but there was some evidence of mutual avoidance, i.e., animals did not occupy the dame areas at the same time; snowshoe hare was the primary food, particularly in winter and during times of hare abundance--frequency of hare in the diet ranged from 38% during a winter of hare scarcity to 94% when hares were abundant; Ruffed Grouse and red squirrel were the numbers 2 and 3 food species in the winter samples, apparently taken opportunistically, while carrion was most used during the hare lows; summer foods were more variable, with slightly more occurrences of mice and voles than hares, although hare still predominated in terms of biomass; lynx were active mostly at night, and apparently spent most of their active periods in hunting;mean daily cruising distances, which varied from 3.0 to 8.8 km in different years, were related to kill success but neither distance travelled or kill success were clearly related to hare abundance; prey consumption rates of tracked lynx varied between 540-680 g (about 0.4-0.5 hare equivalents/day) when hares were abundant--although nutritional requirements were not known, it was concluded that the lower values may not have been sufficient to maintain free-ranging lynx in good condition, resulting in starvation-related losses to kittens and predisposition of adults to losses by trapping and encounters with humans in settled areas.

Brittel, J.D. 1987. Social behavior of lynx (*Felis lynx*) in Washington. *In* B. Townsend (ed.). Abstracts of Pap. Pres., Fourth Northern Furbearer Conference, 3-4 April 1987, Alaska Dep. Fish and Game, Juneau.

020 A) 3; B) Washington; C) 40 live captures of 25 individual lynx, and radio-tracking, December 1980-October 1983.
Life History - hmrange, socbehav.
Population Dynamics - poptrend, popcomp, popreg.
Comments - Abstract only: The sex ratio of captured animals was 50:50; home ranges of residents did not differ between years or between sexes; mean home range size was 62.9 km² (males - 20.5 to 110.6 km²; females - 9.3 to 116.8 km²); the social organization of the studies lynx was believed to be similar to that for bobcats and cougars, involving social intolerance and mutual avoidance; it was concluded that the observed (estimated?) densities on the study area of 2.0 to 2.1 lynx/100 km² was the result of regulation by the social system.

Brooks, A. 1909. The lynxes of British Columbia. Forest & Stream 72: 412.

021 *Comments* - not seen: listed in Sweeney (1977).

Bulmer, M.G. 1974. A statistical analysis of the 10-year cycle in Canada. J. Animal Ecol. 43: 701-718.

022 A) 1; B) Mackenzie; C) Statistical analysis of historic harvest data.
Populations Dynamics - cycles.
Comments - This paper confirms mathematically, the existence and nature of the 10-year cycle, as exemplified by the lynx; the cycle is said to be earlier in the prairie provinces--2 years earlier than in Ontario and Quebec, and earlier than in B.C. by an unspecified period.

Bulmer, M.G. 1975. Phase relations in the ten-year cycle. J. Animal Ecol. 44: 611-620.

023 A) 0; B) Canada; C) Mathematical analysis of historic fur records.
Population Dynamics - cycles.
Comments - The study addresses phase differences (timing of peaks and lows in relation to those of snowshoe hares) between various furbearer species, relating all to reproductive parameters, degrees of density dependence, and degree of dependence on snowshoe hares.

Burris, O. 1971. Lynx management in Alaska. Pages 30-33 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish. and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minn.

024 A) 1; B) Alaska; C) Review of harvests and management/research activities.
Population Dynamics - natality, poptrend.
Species Management - economics, harvest, harv/strategy.
Habitat Management - fire, forestry.
Comments - Writing before the escalation of pelt prices in the late 1970's, the author believed that "...lynx harvests are related to population levels" and that "...low success by hunters and trappers in the years of low lynx populations will result in a self-regulating situation..."; it is noted that the most likely influence of humans on lynx populations would be indirect, through the effects of habitat changes on hare populations--especially fire suppression (believed negative) and logging (believed positive).

Bursey, C.C., and M.D.B. Burt. 1970. *Taenia macrocystis* (Diesing, 1850), its occurrence in eastern Canada and Maine, U.S.A., and its life cycle in wild felines (*Lynx rufus* and *L. canadensis*) and hares (*Lepus americanus*). Can. J. Zool. 48: 1287-1293.

025 A) 0; B) Newfoundland; C) Post-mortem examination of 14 lynx.
Life History - health.
Comments - The cestode indicated was found in all lynx examined,and the snowshoe hare was demonstrated to be an intermediate host; there is no mention of real or apparent effects on the host.

Butler, L. 1942. Fur cycles and conservation. Trans. North Am. Wildl. Conf. 7: 463-472.

026 A) 3; B) Canada; C) Consideration of harvest data.
Population Dynamics - cycles.
Species Management - harvest, harv/strategy.
Comments - This paper considers population cycles from a management rather than purely academic perspective; attention is called to lynx peaks in the 2nd through 4th decades of this century, which are much lower than most of those for 10 or more decades previous--it is alleged that overexploitation was the major causative factor involved; this appears to be the first paper recommending "conservation" (i.e., closure or other harvest restrictions) during the low of the cycle; modeling manually, the author shows that only 1 or 2 years of such restrictions can increase total production over one cycle by up to 180%.

Butler, L. 1953. The nature of cycles in populations of Canadian mammals. Can. J. Zool. 31: 242-262.

027 A) 3; B) Canada; C) Analysis of fur harvest records, 1915-1951, and results of questionnaires on relative abundance of selected species.
Life History - dispersal.
Population Dynamics - cycles.
Comments - This paper is partly in response to Cole's (1951) suggestion that population cycles do nor really exist; subdividing Canada into 63 geographical units, it is shown that local peaks of fur harvest for several species tend to be "...spread over three to four 'good' years which are followed by five or six 'bad' years, when no peaks occur in any section"; lynx data are used to show that different areas of the country may be out of phase, generally with the northern prairies starting the cycle, the west (e.g., B.C.) following in about 1 year and the east (Ontario, Quebec) lagging by 2 years; migration (dispersal) from increasing populations is considered important in contributing both to synchronized growth and hybrid vigor in adjacent areas; it is concluded "...the causal agent of these cycles is the accumulation of favorable factors such as good years, acting over most of the country on populations of different initial densities. Migration from the more favored areas will cause an upswing of the cycle over most of the range."

Campbell, M.J., And A.M. Walker. 1977. A survey of statistical work on the Mackenzie River series of annual Canadian lynx trappings for the years 1821-1934 and a new analysis. J. Royal Stat. Soc. A, 140: 411-431.

028 A) 0; B) Canada; C) Review of historic lynx harvest analyses.
Population Dynamics - cycles.
Comments - This paper is concerned with statistical methods rather than biological processes; no conclusions relevant to management are apparent.

Carbyn, L.N., and D. Patriquin. 1983. Observations on home range sizes, movements and social organization of lynx, *Lynx canadensis*, in Riding Mountain National Park, Manitoba. Can. Field-Nat. 97: 262-267.

029 A) 2; B) Manitoba; C) Radio-tracking 3 animals, 1977-80.
Description - features.
Habitat Characteristics - study/area.
Life History - hmrange, socbehav, movements.
Population Dynamics - natality, mortality, poptrend.
Species Management - harvest, refuges.
Comments - The Manitoba lynx harvest peaked in 1978-79, thus this study probably involves the later stages of the increase phase of the cycle; the collared animals were two adult females (13.6 and 10.9 kg), each with two kittens when captured, and one adult male (15 kg); one female/young group travelled with two other animals, believed to be another adult female with one young, for 30 days; home ranges of the collared females over the November-February period were 138 km^2 and 177 km^2, while the 7.5-month range of the male was 221 km^2; the female ranges overlapped, and there is evidence that the male's range overlapped that of the females; all of 5 marked lynx from RMNP were eventually killed by trappers outside the park, the females within a matter of months--the park is not considered large enough to maintain a viable lynx population with trapping at the periphery; based on the observation of the two family groups traveling together, the potential for adoption of orphaned kittens is discussed.

Chandler, A.C. 1942. *Mesocestoides manteri* n. sp. from a lynx, with notes on other North American species of mesocestoids. J. Parasitol. 28: 227-231.

030 A) 0; B) Nebraska; C) Post-mortem examination of one specimen.
Comments - The species name for the host is not given but, given the location, it is likely that it was a bobcat and not a lynx.

Coggins, V.L. 1969. Lynx taken in northeastern Oregon. Murrelet 50: 16.

031 A) 1; B) Oregon; C) Report of an animal shot in March 1964.
Description - features, distribution.
Comments - Female, in good condition, 14.5 kg; this was the first lynx reported in Oregon since 1935.

Cole, L.C. 1951. Population cycles and random oscillations. J. Wildl. Manage. 15: 233-252.

032 A) 1; B) North America; C) Review of literature and mathematical consideration of "cycles".

Population Dynamics - cycles.
Comments - It is noted that the phenomenon of regular fluctuations is of practical as well as theoretical interest in that "...it suggests possibilities for predicting future outbreaks of noxious organisms and future yields of fish, game, and fur-bearers"; lynx are discussed only as an example of an alleged cyclic species; it is concluded that observed periodicity of wildlife cycles, including the hare-lynx cycles is a result of random variations in the environment.

Cole, L.C. 1954. Some features of random population cycles. J. Wildl. Manage. 18: 2-24.

033 A) 0; B) North America; C) Mathematical consideration of historic fur harvest records.
Population Dynamics - cycles.
Comments - The author again concludes that population cycles result from random, rather than periodic phenomena; lynx not specifically discussed.

Cop, J. 1977. The results of lynx introductions into Kocevsko, Slovenia, Yugoslavia. Proc. Internat. Congr. Game Biol. 13: 372-376.

034 A) 2; B) Yugoslavia; C) Opportunistic observations, 1973-1977.
Life History - food, movements, dispersal.
Population Dynamics - natality, poptrend.
Species Management - transplants.
Comments - Six lynx were successfully introduced into formerly occupied range, and the local population had expanded to as many as 25 animals by the fourth year.

Cowan, I. McT. 1938. The fur trade and the fur cycle: 1825-1857. British Columbia Hist. Quart. 2: 19-30.

035 A) 2; B) British Columbia; C) Compilation of records kept by James Douglas for fur trading posts west of the Rocky Mountains.
Life History - lifehist.
Population Dynamics - cycles.
Species Management - harvest.
Other Topics - history.
Comments - Based on data from Forts Nez Perces, Colville, Thompson's River, Vancouver, Langley, and New Caledonia, lynx populations in B.C. were at highs in 1828, 1836, 1846, and 1855; harvest extremes at New Caledonia ranged from 43 to 4246.

Cowan, I. McT. 1971. Summary of the symposium on the native cats of North America. Pages 2-8 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish. and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minnesota.

036 A) 2; B) North America; C) Review of papers presented.
Description - distribution.
Species Management - harvest, harv/strategy.
Habitat Characteristics - forestry, other/impacts.
Other Topics - history.

Comments - Details of status reports are presented in this bibliography under the separate papers summarized by this author; the possibility of over-harvest during some historical periods and the potential for applying management primarily through restrictions during the cyclic low are mentioned.

De Vos, A., and S.E. Matel. 1952. The status of the lynx in Canada, 1920-1952. J. For. 50: 742-745.

037 A) 2; B) Canada; C) Consideration of lynx harvest data, by province and in Canada as a whole, 1920-1950.
Description - distribution.
Population Dynamics - poptrend, cycles.
Species Management - harvest.
Habitat Management - forestry, other/impacts.
Comments - Based on a 3-fold decrease in harvest between the 1920's and 1940's peaks, plus evidence of shrinking range in the south, the authors concluded that the species was decreasing in Canada; both overtrapping and habitat changes from logging and other clearing were implicated; the national and provincial harvest totals, including that in British Columbia, show similar patterns of cyclic amplitudes over the period studied; some early restrictions on lynx trapping are described: Saskatchewan - closure in 1946, with special permits for harvesting lynx instituted in 1948 and 1949; Manitoba - closure, August 1946 through November 1949, with trapping by permit thereafter; Ontario - closure for 1951-52 season.

Dixon, K.R., and M.C. Swift. 1981. The optimal harvesting concept in furbearer management. Pages 1524-1551 *in* J.A. Chapman and D. Pursley (eds.). Worldwide furbearer conference proceedings, Aug. 3-11, 1980, Frostburg, Maryland.

038 A) 2; B) General; C) Mathematical consideration of multispecies fur harvesting.
Species Management - interactions, harv/strategy.
Comments - not specifically mentioning lynx, it is noted that the concept of maximum sustained yield is not appropriate in situations where several interacting species are harvested simultaneously; the developing optimum yield models are designed to take factors such as inter-species competition and predation into account in establishing harvest goals and strategies.

Doll, A.D., D.S. Balser, and R.F. Wendt. 1957. Recent records of Canada lynx in Wisconsin. J. Mammal. 38: 414.

039 A) 1; B) Wisconsin; C) Incidental observations and specimen records.
Description - features, distribution.
Comments - Report of 2 animals shot, one other seen, and observation of tracks in another location, all in 1954-56; it is speculated that with increasing forest cover in northern Wisconsin, a remnant population may have persisted and may be slowly increasing.

Doucet, G.J., F. Noiseux, R. Lafond, C. Fortin, and D. Banville. 1985. Cooperation between wildlife biologists and lynx trappers: an experiment in the Laurentides Reserve, Quebec. Pap. Pres. Northeast Fish and Wildl. Conf., Hartford, CT.

040 *Comments* - Not seen: Abstract from a computer search by Dialog Information Services, Inc., indicates that a lynx research project was in progress at the time of writing, and involved assistance from trappers in studying effects of trapping on population density, age structure, movements, and behavior; the focus on the paper is apparently the means (system and nature of dialogue between biologists and trappers) rather than results of the research.

Dymond, J.R. 1947. Fluctuations in animal populations with special reference to those in Canada. Trans. Royal Soc. Canada. 41: 1-34.

041 A) 1; B) Holarctic; C) Review of literature and consideration of Hudson's Bay fur records.
Population Dynamics - cycles.
Comments - This paper provides examples of both non-periodic and periodic fluctuations of various animals; the 10-year (hare-based) and 4-year (vole-based) cycles in northern regions are described in detail and a review of various hypotheses as to causes is presented; lynx are mentioned, but are not the primary focus.

Elsey, C.A. 1954. A cause of cannibalism in Canada lynx (*Lynx canadensis*). J. Mammal. 35: 129.

042 A) 1; B) Ontario; C) Incidental observation, March 1951.
Life History -behavior.
Comments - Tracks in the snow indicated that a pair of "young" (yearling?) lynx were hunting together, when a larger lynx rushed out and killed one of them; the dead animal was partially eaten "...from the hind legs and as far forward as the kidneys."

Elton, C.E., and M. Nicholson. 1942. The ten-year cycle in numbers of the lynx in Canada. J. Animal Ecol. 11: 215-244.

043 A) 2; B) Canada; C) Consideration of historic lynx fur returns.
Description - distribution.
Population Dynamics - cycles.
Comments - Among students of the 10-year cycle, this paper is generally acknowledged as the definitive compilation of historic lynx data, from Hudson's Bay Co. records, clearly establishing the existence, periodicity and persistence of the lynx fur cycles in Canada for over 200 years.

Erickson, A.W. 1955. A recent record of lynx in Michigan. J. Mammal. 36: 132-133.

044 A) 1; B) Northern Michigan; C) Report of an animal shot, November 1953.
Description - features, distribution.
Life History - dispersal.
Comments - The animal (male, 11.8 kg) had one toe missing, presumably from a previous trap encounter; it was believed to have been an emigrant from Ontario, within sight across

the St. Mary's River from where it was taken, but assuming the necessity for it to cross on ice, it had been in Michigan at least 7 months.

Errington, P.L. 1954. On the conservation of the lynx in Scandinavia. J. Mammal. 35: 254-255.

045 A) 1; B) Sweden and Norway; C) Review of Scandinavian literature.
Population Dynamics - poptrend.
Species Management - economics, harv/strategy, refuges.
Comments - After much habitat alteration and heavy harvest in the past, Sweden repealed the bounty in 1912, gave the lynx complete protection in 1928, then permitted limiting harvesting after 1943; Norway and Sweden together maintain a "lynx range" serving as a refuge for a populations of a few hundred individuals.

Finerty, J.P. 1979. Cycles in Canadian lynx. Am. Nat. 114: 453-455.

046 A) 1; B) Canada; C) Critique of selected papers on the existence of the 10-year cycle in lynx.
Population Dynamics - cycles.
Comments - The author shows that in suggesting that the lynx cycle precedes the hare cycle in some cases, Gilpin (1973) failed to recognize that the cycle is not synchronous over the whole of Canada; he also presents evidence that Weinstein's (1977) explanations and concerns about lynx population data are not to be taken seriously.

Fox, J.F. 1978. Forest fires and the snowshoe hare-Canada lynx cycle. Oecologia 31: 349-374.

047 A) 3; B) Canada; C) Literature review and analysis of lynx fur returns in relation to forest fire and weather variables.
Habitat Characteristics - vegetation, climate.
Population Dynamics - cycles.
Habitat Management - fire, other/impacts.
Comments - The 10-year hare and lynx cycle is shown to be correlated, both in extent and periodicity, with the frequency and extent of fires, which promote successional habitats in which hare populations may best subsist and grow; it is postulated that fires may be the primary controlling variable, and that precipitation (primarily winter snow characteristics) modifies the response of hares to the abundance of post-fire successional habitat; snow may be important in the extent to which it covers winter food and/or enables hares to browse higher; a "lull" in the lynx cycle (1929-1954) was not related to a similar lull in fires or precipitation factors, and may have been caused by overexploitation of lynx at that time; more recently, intensive fire suppression and subdivision of habitat by land development are correlated with reduced hare cycles in the northcentral United States; a review of the literature shows that population responses to successional changes have been documented for a variety of boreal forest herbivores whose food preferences and requirements overlap those of snowshoe hares.

Gilpin, M.E. 1973. Do hares eat lynx? Am. Nat. 107: 727-730.

048 A) 1; B) Canada; C) Analysis of historic hare and lynx data.
Population Dynamics - cycles.
Comments - The author's theoretical model appears to show that the lynx peak before hares, and on that basis the author suggests that the hares "...could indirectly kill lynx by vectoring disease to them", or that trappers, responding to abundance of hares after sitting out the poor years, might exert pressure on the lynx before the hares had peaked.

Goodchild, S.R., and W.T. Munro. 1980. Preliminary lynx and bobcat management plan for British Columbia. Fish and Wildl. Branch, Ministry of Environ., Victoria. 16pp.

049 A) 2; B) British Columbia; C) Review of existing information.
Habitat Characteristics - vegetation.
Life History - lifehist.
Population Dynamics - poptrend, cycles.
Species Management - economics, harvest, harv/strategy.
Comments - The provincial population is said to vary between 20 000 and 250 000 animals, depending upon the stage of the cycle, and harvest is not believed to have been a significant factor in limiting numbers; a harvest objective of 10% annually, i.e., 2000 to 25 000 animals, is given; no British Columbia research (field or laboratory) is cited; a graph of provincial harvests between 1920 and 1980 indicates a fairly distinct 10-year cycle, with peaks at about the mid-point of every decade.

Grundy, J.S. 1964. A partial bibliography of the genus *Lynx* of North America. Unpubl. Rep., Dep. Wildl. Manage., Univ. Alaska, Fairbanks. 30pp.

050 A) 2; B) North America; C) Literature search for lynx and bobcat.
Other Topics - bibliography.
Comments - Partial list of references through early 1960's.

Gunderson, H.L. 1978. A midcontinent irruption of Canada lynx, 1962-1963. Prairie Nat. 10: 71-80.

051 A) 2; B) northcentral U.S.; C) Records of specimens and sightings.
Description - distribution.
Life History - dispersal.
Comments - A number of dramatic statistics are provided, e.g., in Cook County, Minnesota (NE corner), 147 lynx were bountied in 1962-63 and 137 more in 1963-64, although "not more than half a dozen" had been presented for bounty in that area in the previous 35 years; no more were reported until another (lesser) influx began, in 1971-72; increases in other areas are also reported (North and South Dakota, Montana, Manitoba, and Ontario) and some speculation on causes is offered; this is the best of the various reviews on the 1960's and 1970's "irruptions" in the continental U.S.

Haglund, B. 1966. Winter habits of the lynx (*Lynx lynx* L.) and wolverine (*Gulo gulo* L.) as revealed by tracking in the snow. Viltrevy 4: 81-299.

052 A) 1; B) Sweden; C) Snow-tracking, winters of 1960-64.
Description - features.
Life History - food, activity, hmrange, movements, denning, behavior.
Population Dynamics - natality.
Comments - The larger European lynx (males to 24 kg, females to 22 kg) commonly prey upon roe deer and reindeer in winter, although hares and tetraonids are the primary prey on a year-round basis; daily movements averaged about 8 km; the home range of one male was estimated at about 300 km^2; the animals are generally inactive during the day, and during bad weather.

Halloran, A.F., and W.E. Blanchard. 1959. Lynx from western Wyoming. J. Mammal. 40: 450-451.

053 A) 1; B) Wyoming; C) Review of specimen and sighting records.
Description - distribution.
Life History - dispersal.
Comments - Specimens were obtained in March 1954 (male, 9.9 kg) and November 1957 (female kitten, 4.5 kg), and at least 5 others were taken by state predator hunters 1952-55; the species is considered resident in the northwestern part of the state (where all the above records originated), although it was not considered abundant; at the time of writing, the lynx was classified as a predator (no closed season).

Hancock, J.A., W.E. Mercer, and T.H. Northcott. 1976. Lynx attack on man carrying hares in Newfoundland. Can. Field-Nat. 90: 46-47.

054 A) 1; B) Newfoundland; C) Report of isolated event, 1 November 1974.
Life History - food, behavior.
Species Management - harvest.
Comments - A "medium-sized" female lynx leaped on trapper from a tree--presumably focusing on the hares he was carrying; this was during a low of the cycle--that trapper's harvests between 1969-70 and 1974-75 given as 50, 41, 30, 24, 19, and 11 lynx, respectively.

Hell, P. 1970. Preliminary report on the study of the food of the lynx (*Lynx lynx*) in the Slovakian part of the Carpathians. Lynx 11: 113-117.

055 *Comments* - Not seen; listed in Sweeney (1977).

Herrendschmidt, V., F. Leger, and G. Terrier. 1986. Use of space by lynx introduced into the Massif Vosgien. Preliminary results. Gibier Faune Sauvage 3: 67-81.

056 *Comments* - Not seen; listed in the Wildlife Review 203: 86-97.

Hickey, J.J. 1954. Mean intervals in indices of wildlife populations. J. Wildl. Manage. 18: 90-106.

057 A) 1; B) Canada; C) Review of historic fur returns and papers on cycles.
Population Dynamics - cycles.
Comments - From the summary: "At the continental level, lynx pelt collections exhibit a 9- to 10-year cycle; muskrats do not. At the regional level, the cycle is present in (older) lynx data for Hudson's Bay COmpany districts; it is obscured in recent provincial indices for lynx...no satisfactory evidence for a 10-year cycle in British Columbia or the Maritimes was encountered."

Iurgenson, P.B. 1955. Ecology of the lynx in forests of the central zone of the USSR. Zool. J. 34: 609-620.

058 A) 2; B) USSR; C) Regular snow-tracking, 1930's and 1940's.
Habitat Characteristics - vegetation, cover.
Life History - food, nutrition, hmrange, denning, behavior.
Population Dynamics - poptrend, harvest.
Habitat Management - forestry.
Comments - Estimated densities of one lynx per 7-20 km^2, depending on stage of cycle (i.e., only 3-fold differences between high and low); as in North America, hares were the primary food in most areas, and lynx numbers and movements were related to those of hares; in relation to peaks based on fur harvest records, the author notes that "...the yield is the result not of increase in the number of species which is being procured, but of a shortage of food."

Johnston, D.H., and I.D. Watt. 1981. A rapid method for sectioning undecalcified carnivore teeth for aging. Pages 407-422 *in* J.A. Chapman and D. Pursley (eds.). Worldwide furbearer conference proceedings, Aug. 3-11, 1980. Frostburg, Maryland.

059 A) 2; B) General; C) Review of methods and interpretations, and development of a new technique.
Species Management - age/tech.
Comments - A new method that does not involve decalcifying, and that enables processing of up to 100 teeth per day, is described; it is reported to have been used successfully on lynx teeth; in the review of interpreting lines in teeth, it is noted that any events that affect mineralization "...e.g., sickness, trauma or lactation...can be expected to leave a record in the teeth."

Keener, J.M. 1971. The status and management of the bobcat and Canada lynx in Wisconsin. Pages 35-36 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minnesota.

060 A) 1; B) Wisconsin; C) Review of management and population status.
Species Management - harv/strategy.
Habitat Management - other/impacts.

Comments - The lynx is rare in Wisconsin, its range there believed limited primarily by agricultural clearing; there is believed sufficient habitat for it to continue to occupy its present range in the northern part of the state, and it was "completely protected" there from 1957 to the time of writing.

Keith, L.B. 1974. Some features of population dynamics in mammals. Proc. Internat. Congr. Biol. 11: 17-58.

061 A) 2; B) Mostly North America; C) Review of literature.
Life History - socbehav.
Population Dynamics - cycles, popreg.
Comments - This paper provides a useful summary of the various schools of thought on natural regulation of animal populations, then focuses on the following subjects: 1) impacts of predation on mammal populations, 2) predator population dynamics, 3) cyclic fluctuations, and 4) ungulate irruptions; in the context of this bibliography on lynx, the author summarizes 12 years of data on the snowshoe hare cycle at Rochester, Alberta, with the following conclusions: the cycle can be explained in terms of "...a hare-vegetation interaction which initiates the (hare) population decline and sets the stage for a predator-hare interaction which extends it."; the population dynamics of lynx is compared to that of mountain lions--from available evidence it is concluded that unlike the case for mountain lions, lynx populations are not limited by social behavior (territoriality) because of their dependence on a fluctuating and unstable prey base (the cyclic hare).

Keith, L.B., A.W. Todd, C.J. Brand, R.S. Adamcik, and D.H. Rusch. 1977. An analysis of predation during a cyclic fluctuation of snowshoe hares. Proc. Internat. Congr. Game Biol. 13: 151-175.

062 A) 2; B) Alberta; C) Synthesis of Rochester study results (hare, grouse, and predator populations) over one complete cycle.
Habitat Characteristics - study/area.
Life History - food.
Population Dynamics - poptrend, popreg, cycles.
Comments - This paper examines the response and role of several predators, including lynx, to changing snowshoe hare numbers; on average, predator populations showed a 4-fold change in numbers between peak and low (lynx = 3.8), while that for hares was 31.3; it is concluded that predator numbers and use of hares increases in response to increasing hare numbers, and may remain relatively high for 2-3 years following the hare decline--predator numbers eventually decline, but their continued pressure on the declining hare population may deepen and extend the hare low.

Koehler, G.M. 1987a. Preliminary report: the ecology of the lynx in northcentral Washington. *In* B. Townsend (ed.). Abstracts of Pap. Pres., Fourth Northern Furbearer Conf., 3-4 April 1987, Alaska Dep. Fish and Game, Juneau.

063 A) 3; B) Washington; C) Mostly radio-tracking?
Description - distribution.
Life History - food.

Population Dynamics - natality, poptrend.
Comments - Abstract only: The study, an extension of one commenced in the area in 1980 (Brittell 1987), is to determine population dynamics and habitat requirements of a population occurring at the (southern) periphery of its range; preliminary findings are of low density (2.3-3.1 lynx/100 km²) and low productivity (1-1.3 kittens/year), similar to parameters in more northerly populations during hare lows; foods in Washington include snowshoe hares, tree squirrels, and microtines.

Koehler, G.M. 1987b. The ecology of the lynx (*Lynx canadensis*) in northcentral Washington. Unpubl. Prog. Rep., Wildl. Res. Inst., Univ. Idaho, Moscow. 25pp.

064 A) 3; B) Washington; C) Radio-tracking 7 animals (5 males, 2 females), and snow-tracking.
Descriptions - features, distribution.
Habitat Characteristics - study/area, vegetation, cover.
Life History - food, hmrange, socbehav, denning.
Population Dynamics - natality, mortality, poptrend.
Habitat Management - fire, forestry.
Comments - This is a report on a continuing study of lynx at the southern edge of their range, and just south of the B.C. border; a total of 28 different lynx have been handled on the study area since 1981; male home ranges averaged 67.8 km², while those of females were 41.5 km²; the two radio-collared females produced 7 kittens in 1986 (July), but only 1 of those (14%) survived to winter--there was also an uncollared female with 3 kittens on the area in winter 1986-87; the two females also both had litters in July 1987, one apparently only having 1 kitten and the other undetermined; adult mortality is low, with annual rates among the collared sample of 21% from 1981-83, 27% for 1986, and 0% for 1987--one adult male is believed to have died as a result of predation (predator not specified); lynx selected for young lodgepole pine forests (both post-fire and post-logging) and mature spruce-subalpine fir forests--the pine types supported the most evidence of hare use, and thus were probably used primarily for hunting, while all 4 of the natal dens were found in mature conifer habitats with an abundance of blowdown; analysis of 33 scats indicated that the most used food was snowshoe hare (79.3% frequency of occurrence); other foods included red squirrels (24.1%), mule deer (6.9%) and deer mice (3.4%).

Koehler, G.M., M.G. Hornocker, and H.S. Hash. 1979. Lynx movements and habitat use in Montana. Can. Field-Nat. 93: 441-442.

065 A) 2; B) Montana; C) Radio-tracking, 2 adults, 1977.
Habitat Characteristics - study/area, cover.
Life History - hmrange, movements.
Population Dynamics - mortality.
Comments - An adult female, caught in mid-January, was monitored for only 2 weeks before it died, apparently killed by a cougar; an adult male was monitored for 7.5 months, during which time it used a home range of 36 km²; 90% of 29 locations were in a young (67-year-old) burn thickly stocked with lodgepole pine and supporting good populations of snowshoe hares.

Koonz, W.H. 1976. A biological investigation of lynx in Manitoba. Manitoba Dep. Renewable Resources Transport. Serv., Res. Branch Rep. 76-2. 35pp.

066 *Comments* - Not seen; cited in Mech (1980).

Kumar, V., J. Martelmans, J. Vercruysse, and F. Ceulemans. 1975. Chemotherapy of helminthiasis among wild mammals. I. Lungworm infection of *Felis* (*Lynx*) *canadensis* (Kerr). Acta. Zool. Pathol. Antverpiensia 61: 85-89.

067 A) 0; B) General; C) Treatment of a captive specimen.
Life History - health.
Comments - A newly acquired specimen, still under quarantine, was discovered to have a lungworm infection which was successfully treated with Mebendazole; the source location of the captive lynx was not given.

Kurten, B., and R.L. Rausch. 1959. Biometric comparisons between North American and European mammals. II. A comparison between the northern lynxes of Fennoscandia and Alaska. Acta Arctica 11: 21-44.

068 A) 0; B) Holarctic; C) Examination of museum skull specimens.
Description - features, taxonomy.
Other Topics - zoogeography, morphology, evolution.
Comments - North American lynx are much smaller than the European form; among North American specimens, males are slightly larger than females; North American and European lynx are morphologically closer than are North American lynx and bobcat; tentatively, it is considered that the differences between lynxes and the bobcat is only at the subspecies level.

Kvam, T. 1984. Age determination in European lynx by incremental lines in tooth cementum. Acta Zool. Fenn. 171: 221-223.

069 *Comments* - Not seen; cited in O'Connor (1984) and Quinn and Thompson (1987).

Lack, D. 1954. Cyclic mortality. J. Wildl. Manage. 18: 25-37.

070 A) 1; B) North America; C) Review of literature on population cycles.
Life History - food, dispersion.
Population Dynamics - cycles.
Comments - Notes that the peak of the lynx cycle may differ by 2-4 years in different areas of Canada, but that emigration tends to even things out in subsequent years; apparently there was a conspicuous "emigration" of lynx in 1916-17, following the hare peak of 1914-15.

Langford, E.V. 1974. *Acholeplasma laidlawii* and *Pasteurella multocida* isolated from the pneumonic lung of a lynx. J. Wildl. Dis. 10: 420-422.

071 A) 0; B) Alberta; C) Post-mortem examination of one specimen.

Life History - health.
Comments - The animal (age and sex unspecified) was behaving in a peculiar manner and was shot; it proved to have had pneumonia, and the bulk of the paper discusses the actual or potential role of various pathogens in producing the pneumonia; the date of kill was not recorded, but assuming it was shortly prior to publication (i.e., 1973-74), it would have been during the lynx population decline in Alberta (as described by Brand and Keith 1979).

Legendre, P., F. Long, R. Bergeron, and J-M. Levasseur. 1978. Aerial survey of the fauna in middle northern Quebec. Can. J. Zool. 56: 451-462.

072 A) 1; B) Quebec; C) 1368 km of aerial transects, March 1976.
Description - distribution.
Population Dynamics - poptrend.
Species Management - census.
Comments - The primary purpose of the survey was to describe fauna in relation to biogeoclimatic units mapped previously; tracks of hares, lynx, and other furbearers were recorded and local indices of occurrence for each were established (Note: paper in French with English summary).

Lien, J., and W.E. Mercer. 1980. Control of lynx predation on caribou calves by flavor illness aversions. Pages 725-727 *in* E. Reimers, E. Gaare, and S. Skjenneberg (eds.). Proc. 2nd Internat. Reindeer/Caribou Symp., Roros, Norway, 1979. Direktoratet for Vilt og Ferskvannsfisk, Trondheim.

073 A) 1; B) Newfoundland; C) Studies with two captive lynx, and in a wild setting on a small island.
Life History - food, behavior.
Species Management - field/tech.
Comments - Initial experiments proved promising; the captive lynx became averse to caribou meat, and conditioned lynx on the small island did not kill any of five caribou calves produced there in the year of study.

Lindemann, W. 1955. Uber die jugendentwicklung beim luchs (*Lynx l. lynx* Kerr) und bei der wildkatze (*Felis s. silvestris* Schreb.). Behaviour 8: 1-45.

074 A) 1; B) Poland; C) Comparisons in development, ontogeny of various behavior, sensory capabilities, and intelligence of lynx versus a species of wildcat.
Life History - socbehav., behavior.
Other Topics - physiology.
Comments - From English summary: body development and maturation of "inborn behavior" are slower in the lynx; suckling occurs over 6 months and parental care by the mother extends over 10 months in the lynx, as compared to 4 and 5 months, respectively, in the cat--before family break-up there is increasing intolerance and "prey envy" between siblings; lynx have excellent visual and auditory senses (discrimination of colors, degrees of brightness, shapes, color-tones, variations in pitch), but a less well-developed sense of smell; nevertheless, lynx reacted strongly to the smell of lynx feces, sexual odors, and

certain other "strange" olfactory stimuli; orientation and homing are largely visual, and lynx were shown to have an excellent memory for physical features within their home ranges.

Loewen, S.L. 1929. A new cestode, *Taenia rileyi* n. sp. from a lynx. J. Parasitol. 21: 469-471.

075 A) 0; B) Minnesota; C) Post-mortem examination of one specimen.
Life History - health.
Comments - A few individuals of a helminth species not previously recorded in lynx were recovered from the intestine of the specimen examined; no mention of health or population implications for lynx.

Maliepaard, H.S. 1971. A report on wildcats in Saskatchewan. Pages 38-44 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on native cats of North America. U.S. Bur. Sports Fish and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minnesota.

076 A) 1; B) Saskatchewan; C) Review of harvest and management information.
Life History - dispersal.
Species Management - harvest.
Comments - It is noted that the species was only poorly known in the province, as there had been no studies on population dynamics; most annual harvests between 1910 and the mid-1950's were low (fewer than 2000 pelts) but that increased to 11 100 in 1959, 6000-8000 in each of the years 1960-62, and then generally decreased again until the next peak (10 294 in 1969); emphasizing that there are no concrete data, the author notes his impression that occurrence in the southern half of the province varies greatly, with great influxes following hare declines in the north.

McCord, C.M., and J.E. Cardoza. 1982. Bobcat and lynx. Pages 728-766 *in* J.A. Chapman and G.A. Feldhamer (eds.). Wild mammals of North America. Biology, management, and economics. Johns Hopkins Univ. Press, Baltimore.

077 A) 2; B) Holarctic; C) Review of literature.
Description - features, taxonomy, distribution.
Habitat Characteristics - vegetation, climate.
Life History - lifehist.
Population Dynamics - natality, mortality.
Species Management - age/tech, field/tech, repro, economics, harvest, harv/strategy, transplants.
Habitat Management - fire, forestry, other/impacts.
Other Topics - bibliography, physiology, morphology, genetics.
Comments - The biology and management of both lynx and bobcat are reviewed together, and some aspects are compared, although the bulk of the review is devoted to the more frequently studied bobcat; it is noted that since northern lynx are now considered one circumpolar species, researchers in North America should keep abreast of findings in Eurasia; most findings are summarized from other papers in the present bibliography--additional items of interest are as follows: **PHYSIOLOGY AND MORPHOLOGY** - the lynx has well-developed eyesight and hearing, but a relatively poor sense of smell; it is well-adapted to cold, deep-snow conditions. **REPRODUCTION** - in both species, the

corpea lutea do not degenerate into corpora albicantia--rather they persist through subsequent ovulations, although the recent and older corpora can be distinguished by structural and/or color differences; lynxes are assumed to be induced ovulators, but there is some evidence that bobcats may ovulate spontaneously; females are capable of breeding in their first year, but males may not be. **MORTALITY** - little is known of pre-natal mortality i either species, but high kitten mortality has been recorded for both species, especially during periods of food scarcity. There is little direct information on adult mortality other than that caused by humans. **PARASITES AND DISEASES** - documentation of diseases in wild populations of both species are scarce--no epizootics or die-offs from heavy parasite infestations have been recorded. It is speculated that "...they may be less vulnerable to this type of mortality due to their solitary nature and their propensity to change denning and resting areas frequently." **ECONOMIC STATUS** - the primary role of lynx in the economy is in its fur value; due to the cyclic nature of lynx harvests, it is difficult to express that value in terms of averages for any particular area, but in North America i recent decades the number of pelts produced have been 1400-9000 in Alaska, 130-975 in the contiguous U.S., and 13 000 to 53 000 in Canada; unlike the case for bobcats, depredations are of little interest or concern in the management of lynx. **MANAGEMENT** - transplants have thus far been attempted only in Europe, and at least one of those efforts appears to have been successful (see Cop 1977); it is noted that log-term, intensive research of representative populations of both species is needed to enable better design and interpretation of monitoring programs and more effective management.

McKay, D.I. 1985. Lynx in Manitoba: situation report. Unpubl. Rep., Wildl. Branch, Manitoba Nat. Resources, Winnipeg. 4pp.

078 A) 3; B) Manitoba; C) Statement of management rationale and strategy.
Population Dynamics - poptrend.
Species Management - economics, harvest, harv/strategy.
Comments - The lynx harvest in Manitoba has decreased since 1978-79, reaching a low of 596 pelts in 1983-84, and the trend over the past 40 years has been for decreases in harvest at the cyclic peaks; some major considerations in lynx management are high pelt value, the problem of accidental lynx catches in sets for other furbearers even with reduced or closed seasons, potential "bootlegging" of pelts across jurisdictional borders from closed to open areas, and reaction of anti-trapping organizations to non-action in relation to low and/or declining populations; it is recommended that a national system be developed, to establish open seasons in relation to the varying population trend across the country, that actions be taken within the fur industry to "enable a reduction of pelt value during critical periods...", and that wildlife agencies increase their monitoring activities.

Mech, L.D. 1973. Canadian lynx invasion of Minnesota. Biol. Conserv. 5: 151-152.

079 A) 2; B) Minnesota; C) Compilation of incidental observations.
Description - distribution.
Life History - dispersal.
Population Dynamics - poptrend.
Comments - Notes that an "irruption" of lynx in 1962-63 subsided within 2 years, then recurred in 1972; most animals had little or no tooth wear and appeared to be in good

physical condition; although two instances of females with young were recorded, ti was presumed that most of the increase of animals was due to dispersal from Canada.

Mech, L.D. 1977. Record movement of a Canadian Lynx. J. Mammal. 58: 676-677.

080 A) 1; B) Minnesota-Ontario; C) Observation of a marked lynx.
Description - distribution.
Life History - movements, dispersal.
Comments - A female lynx, believed young when captured and collared in northeastern Minnesota (November 1974), was taken by a trapper in southeastern Ontario, 483 km distant (January 1977).

Mech, L.D. 1980. Age, sex, reproduction, and spatial organization of lynxes colonizing northeastern Minnesota. J. Mammal. 61: 261-267.

081 A) 3; B) Minnesota; C) Radio-tracking and ear-tagging (incidental captures during a wolf study), and examination of carcasses, 1972-1978.
Life History - hmrange, socbehav, dispersal.
Population Dynamics - natality, mortality, poptrend, popcomp.
Species Management - harvest.
Comments - The study animals were characterized as emigrants from Ontario and Manitoba, during cyclic highs in those provinces (especially in 1972); despite the absence of a secure resident population and little evidence of local reproduction, 215 animals were harvested in Minnesota in 1972, and 691 in 1973, as compared to only 88 in 1974 and 0 in 1975; there was some evidence that males were more vulnerable to harvest than were females; home ranges of studied animals were larger than those documented in other areas (females 51-122 km^2). males 145-243 km^2).

Moran, P.A.P. 1949. The statistical analysis of the sunspot and lynx cycles. J. Animal Ecol. 18: 115-116.

082 A) 1; B) Canada; C) Analysis of historic lynx fur data.
Population Dynamics - cycles.
Comments - Because the cycle of sunspots is shown to be out of phase with the lynx cycle at times, sunspots are "decisively ruled out" as a causative factor in the lynx cycle.

Moran, P.A.P. 1953a. The statistical analysis of the Canadian lynx cycle. I. Structure and prediction. Aust. J. Zool. 1: 163-173.

083 A) 1; B) North America; C) Consideration of historic lynx fur data particularly for the Mackenzie River region, 1821-1934.
Population Dynamics - cycles.
Comments - It is concluded that the lynx harvest data "...are at least consistent with the idea that the cyclic behaviour is due to factors intrinsic to the biological system."

Moran, P.A.P. 1953b. The statistical analysis of the Canadian lynx cycle. II. Synchronization and meteorology. Aust. J. Zool. 1: 291-298.

084 *Comments* - Not seen.

More, G. 1976. Some winter food habits of lynx in the southern Mackenzie District, NWT. Can. Field-Nat. 90: 499-500.

085 A) 1; B) NWT; C) Examination of 14 scats, deposited winter 1973-74.
Life History - food.
Comments - Only four food species were represented--snowshoe hare 83.3%, grouse 16.6%, red squirrel 55.5%, red-backed vole 5.5% (frequency of occurrence); both hares and lynx were at a low in the cycle.

Nava, J. 1970. The reproductive biology of the Alaska lynx. Unpubl. M.Sc. Thesis, Univ. Alaska, Fairbanks. 141pp.

086 A) 2; B) Alaska; C) Examination of 1105 lynx carcasses, 1964-65.
Population Dynamics - natality.
Comments - Yearlings predominated in the harvest (60%), but kittens were under-represented; Alaskan lynx breed in late March or early April and give birth in June; data on reproductive parameters suggested that decreased reproduction rather than mortality of young is the primary factor in declining populations.

Nellis, C.H. 1971. The lynx in the northwest. Pages 24-28 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish. and Wildl.,Fed/ Bldg., Fort Snelling, Twin Cities, Minnesota.

087 A) 1; B) Idaho, Montana, Oregon, Washington; C) Review of harvest and management status.
Description - distribution.
Population Dynamics - poptrend.
Species Management - harvest, harv/strategy.
Habitat Management - forestry.
Comments - Lynx were considered common (increasing) in Montana, rare to common (increasing) in Idaho and Washington, and very rare (decreasing) in Oregon; a 3-month trapping season was in effect in Washington, but there was no closed season and the animal was classified as a predator, or was unclassified, in the three other states; the only data on numbers is from harvests--it is not known if the animal is cyclic in the Northwest, but a dramatic increase in harvest in 1962-63 is speculated to have been caused by dispersal from Canada following hare declines in 1961-63; logging is portrayed as a potential benefit to lynx in producing young forests in which hares thrive, but it is noted that the beneficial effect could be reduced by some silvicultural practices that, by design or inadvertently, reduce the utility of cut areas to hares.

Nellis, C.H., and L.B. Keith. 1968. Hunting activities and success of lynxes in Alberta. J. Wildl. Manage. 32: 718-722.

088 A) 3; B) Alberta; C) Snow-tracking, 1964-64 through 1966-67.
Habitat Characteristics - climate.
Life History - food, activity, movements.
Species Management - field/tech.
Comments - Trailed lynx made kill, on average, every other night; About 70% of the utilized prey (weight) was snowshoe hare, 17% was carrion, and 11% Ruffed Grouse; hunting effort was greater, and success lower, in 1967 when prey populations were highest--that result was postulated to be due to poorer hunting conditions, as related to snow cover characteristics, in that year.

Nellis, C.H., and S.P Wetmore. 1969. Long-range movement of lynx in Alberta. J. Mammal. 50: 640

089 A) 2; B) Alberta; C) Observations of a marked study animal.
Life History - movements, dispersal.
Comments - An adult male, resident in the Rochester study area for about 3 years, lost a foot in a trapping incident and subsequently moved 164 km northwest in 163 days, and was shot in a chicken coop; both lynx and hare populations in the study area were increasing at the time.

Nellis, C.H., S.P. Wetmore, and L.B. Keith. 1972. Lynx-prey interactions in central Alberta. J. Wildl. Manage. 36: 320-329.

090 A) 3; B) Alberta; C) Snow-tracking, opportunistic study of marked animals, scat analysis, and autopsy of carcasses from trappers,1964-1967 (period of low and beginning of increase phase for hares).
Life History - food, nutrition, hmrange, movements.
Population Dynamics - natality, mortality, poptrend, popreg, cycles.
Species Management - repro.
Comments - The winter diet of lynx on the Rochester study area consisted of 76% hare, 10% carrion, 9% Ruffed Grouse, 3% red squirrel, and 2% small mammals and birds; average home range size for adults was estimated at 15 km^2; the estimated study area lynx population during the 1964-65 through 1967-68 winters, respectively, was 11, 5, 3, and 9, with kittens present (6) only in the last year;the only documented adult mortality was at the hands of humans (3-4 of 17), although the fates of the others was not known;there was some evidence that mortality occurs primarily in winter,and was highest in the unusually severe winter of 1964-65; low to nil recruitment during the low of the hare cycle was believed due primarily to early kitten mortality rather than reproductive failure.

O'Connor, R.M. 1984. Population trends, age structure, and reproductive characteristics of female lynx in Alaska, 1961 through 1973. Unpubl. M.Sc. Thesis, Univ. Alaska, Fairbanks. 111pp.

091 A) 3; B) Alaska; C) Examination of 3130 carcasses collected over one complete population cycle, 1961-62 through 1972-73.
Life History - dispersal.
Population Dynamics - natality, poptrends, cycles.

Species Management - age/tech, kill/tech, repro, economics, harvest, harv/strategy.
Comments - A major factor in forcing increased recent interest in lynx management in Alaska has been fur value, with average pelt price increasing 8-fold ($35 to $263) between 1970-71 and 1982-83; CITES (Convention on International Trade of Endangered Species) is also described as a catalyst to recent research, in its requirements that signatory jurisdictions justify their management programs; this study appears to be the first based on carcasses collected over one complete cycle, and involves the largest collection of lynx specimen material analyzed in any one study; questionnaire results on relative abundance of hares and lynx during the study period were considered more reliable indicators of population trends than were harvest records; regional differences (asynchrony) in the lynx cycle was documented, but it was noted that implementation of management at the regional level may be premature, because the importance of lynx dispersal in local population processes is yet to be evaluated; lynx populations fluctuated in response to hare abundance, becoming abundant, peaking, or becoming scarce 1 year after hares reached similar levels in 8 of 9 region-winters--however, harvest did not peak at the same time as the population, but followed the peak by up to 3 years; significant differences in age structure of the harvest sample occurred between regions in 6 of 10 winters and between some winters in all regions; approximately 3/4 of the harvest was composed of young animals (kittens plus yearlings) during first winters following hare abundance, but that reversed to 3/4 adults during first winters following years of hare scarcity; the highest proportion of kittens occurred from 1 to 4 winters prior to lynx populations, nor afterward as reported elsewhere; all measures of lynx reproduction, for both yearlings and adults, were higher when hares were abundant than when hares were scarce; yearlings were less productive than adults, but that was particularly evident during periods of hare scarcity; between periods of hare abundance and scarcity, yearlings decreased in ovulation rate from 97% to 18% and in implantation rate (among ovulators) from 72% to 18%l judging from the correlation between measures of lynx productivity and hare abundance, nutrition is probably the primary cause of observed differences during the cycle; lynx population levels could not be reliably predicted solely from data on reproductive rates from the previous year, probably because other factors such as neonate mortality and dispersal are occasionally more important; this study indicates that the temporal and regional relationships among lynx recruitment, lynx population peaks, and lynx harvest peaks may not be as simple as previously thought--it is noted that "...declines are detected *after* they occur by examining records of harvest...(and)...at that point lynx reproduction may already have declined for several years and it may be relatively late for an effective response by the manager."

O'Connor, R.M., D. J. Reed, and R.O. Stephenson. 1987. Lynx population dynamics and harvest-insight from a computer model. *In* B. Townsend (ed.). Abstracts of Pap. Pres., Fourth Northern Furbearer Conference, 3-4 April 1987, Alaska Dep. Fish and Game, Juneau.

092 A) 3; B) general; C) Modeling of lynx population dynamics from data presented in the literature.
Population Dynamics - natality, poptrends, popcomp.
Species Management - harvest, harv/strategy.
Comments - Abstract only: The population dynamics model was designed to "...Maximize the interpretive value of our harvest data..."; preliminary conclusions are that 1) lynx

populations have a large potential for increase under favorable conditions, 2) small changes in sex ratio may substantially affect population growth during hare abundance, and 3) "In some situations, a...population harvested at two different rates may yield the same three-year harvest; however, the number of lynx remaining after the three-year harvest may be much higher with the lower harvest rate."

Parker, G.R. 1981. Winter habitat use and hunting activities of lynx (*Lynx canadensis*) on Cape Breton Island, Nova Scotia. Pages 221-248 *in* J.A. Chapman and D. Pursley (eds.). Worldwide Furbearer Conference Proceedings, Aug. 3-11, 1980, Frostburg, Maryland.

093 A) 3; B) Nova Scotia; C) Snow-tracking, 192 km of lynx trails, January through mid-April 1978.
Habitat Characteristics - study/area, vegetation. cover, climate.
Life History - food, nutrition, activity, movements, denning, behavior.
Species Management - field/tech.
Comments - Lynx were selective in use of habitat types, apparently preferring mature conifer and advanced successional (22-28 years post-logging) types; 198 of 200 hunting chases were directed at snowshoe hares, and overall success rate was 17%; hunting success improved through the winter (14% in January to 26% in April), and may have been due to changing snow conditions and/or increased experience of young lynx; individuals traveled an average of about 8 km and killed an average of one hare per day (24 hours); hunting success increased with group size, as animals hunted in a fanned-out, cooperative fashion.

Parker, G.R., J.W. Maxwell, L.D. Morton, and G.E.J. Smith. 1983. the ecology of the lynx (*Lynx canadensis*) on Cape Breton Island. Can. J. Zool. 61: 770-786.

094 A) 3; B) Nova Scotia; C) Radio-tracking, snow-tracking, necropsy of carcasses from trappers, analysis of harvest data.
Description - features, distribution.
Habitat Characteristics - study/area, vegetation, cover.
Life History - food, nutrition, activity, hmrange, movements,health, behavior.
Population Dynamics - natality, mortality, poptrend, popcomp.
Species Management - age/tech, field/tech, repro, harvest, interactions, harv/strategy, refuges.
Habitat Management - forestry, other/impacts, hab/strategy.
Comments - This study involves a lynx population that is completely isolated from the continental population; the sex ratio of harvested animals was high to males in 1977-78 (68:32), but did not differ from 1:1 in the following 2 years; yearlings comprised the dominant age class in the harvest (52%, 67%, and 39%), while kittens declined (29% to 9% to 2%) during the 3 years of study; within the trapping season, the proportion of yearlings decreased from November through March, while kittens increased and the proportion of adults remained fairly stable during that period--females were more abundant in the harvest in November and December,with males dominating later; the proportion of parous females (those with placental scars) decreased progressively over the 3 years, but particularly in the case of yearlings (67%, 29%, 0%)--numbers of placental scars also decreased in yearlings (3.7, 2.7, -), but increased in older females (3.3, 3.8, 3.8); the above patterns coincided with a decline of snowshoe hares (1000/100 ha in 1977 to 170/100 ha in

1979 in the best habitats); fat deposits were least in yearling lynx--incidence and extent of fat on harvested animals declined from November through December, but increased or leveled off from January through February; by far the primary dietary item was snowshoe hare (97% occurrence in winter stomachs, 93% in winter scats, and 70% in summer scats)--white-tailed deer was second (5%, 5%, and 9%, respectively), while small mammals (especially red-backed vole and red squirrel) and unidentified birds accounted for most of the remainder; daily/seasonal activity, movements, and home range patterns for 3 radio-collared animals (1979) are described--seasonal home ranges of the two adults (male: 12 and 26 km^2;female 19 and 32 km^2) overlapped considerably, with the female's range approximately 30% larger than that of the male in both winter and summer; for both adults, summer home ranges were almost twice as large as those in winter; the juvenile, a female, had a smaller and less seasonally variable home range (10 and 8 km^2), maintained separate from those of the two adults;hunting success of lynx increased as winter progressed, and was greater for groups (usually females with young)than for single animals; a density of 20 lynx/100 km^2 was estimated for the 60 km^2 study area in winter 1978-79; 65% of the projected population was removed by trapping in the following winter--there is evidence that vulnerability to trapping is related to body condition and/or experience, thus explaining the harvest pattern of yearlings and/or leanest animals early in the winter and other, more experienced or protected (kittens with their mothers) classes later; because there is little "refuge" area on Cape Breton Island, the recommended harvest management strategy is for restricted harvests (e.g., by trapper quotas) in years of high recruitment and closures during the lows--monitoring of snowshoe hare densities and of sex and age structure of the harvest are believed essential for effective regulations; it is also noted that there is potential for reducing overall harvests and changing harvest composition by manipulating timing and duration of the trapping season; extensive clearcutting of the mature conifer forest on the island is considered a potential threat to the island lynx population; collared animals selected for regenerating mixed forest habitats--the best local habitats for snowshoe hares--but large clearcuts are of little use to either hares or lynx in winter for the first 20 years, and may be used only at the periphery for many years thereafter; it is considered too late to integrate forest and lynx (hare) management on the island, but it is implied that reduction of clearcut size and interspersion of uneven-aged cuts and mature forest would have been desirable; there is some evidence that the bobcat, recently arrived on the island, may be competitively excluding lynx in the lowlands.

Pence, D.B., H.P. Samoil, and J.E. Stone. 1978. Spirocercid stomach worms (Nematoda: Spirocercidae) from wild felids in North America. Can. J. Zool. 56: 1032-1042.

095 A) 0; B) Alberta; C) Post-mortem examination of 33 lynx specimens, collected in the Swan Hills area, 1971-73.
Life History - health.
Comments - These helminths were considered common in lynx, occurring in 24 of the specimens examined (73%); some damage to stomach tissues associated with the worms was apparent, but "...there was no evidence, histologically, of disturbance to normal function."

Penner, D.F. 1979. Furbearer studies in the Liard River Valley, British Columbia. Prelim. Rep. for B.C. Hydro and Power Authority, McCourt Management Ltd., Vancouver. 121pp.

096 A) 2; B) British Columbia; C) Snow-tracking.
Population Dynamics - poptrend.
Comments - not seen: cited in Stephenson (1986) in relation to lynx track frequencies along transects.

Pratt, L.W. 1942. Bregmatic frontanelle bones in the genus *Lynx*. J. Mammal. 23: 411-416.

097 *Comments* - Not seen: listed in Sweeney (1977).

Pulliainen, E. 1981. Winter diet of *Felis lynx* L. in SEW Finland as compared with the nutrition of other northern lynxes. Z. Saugetierk. 46: 249-259.

098 A) 1; B) Finland; C) Examination of 88 stomachs and 45 intestinal tracts (winter-trapped specimens) over the 13-year period (1967/68-1979/80).
Life History - food.
Comments - The study area is characterized as one in which there are no roe deer available; hares predominated in the studies samples (80% by frequency and 86% by weight); other prey included domestic and ranch animals, a red fox, small rodents, and a few birds; a review of food study results from other areas, both in Europe and North America, is given, confirming the general predominance of mammals in the lynx diet; aspects of sexual dimorphism in size are discussed--it is concluded that "...female lynx are small because of low total energy requirements and their ability to channel...excess energy into reproduction, and the males are large as a result of sexual selection."

Pulliainen, E., and V. Hyypia. 1975. [Winter food and feeding habits of lynxes (*Lynx lynx*) in southeastern Finland.] Suomen Riista 26: 60-63.

099 *Comments* - Not seen; cited and described as a preliminary report in relation to Pulliainen (1981).

Quinn, N.W.S., and J.F. Gardner. 1984. Relationships of age and sex to lynx pelt characteristics. J. Wildl. Manage. 48: 953-956.

100 A) 3; B) Ontario; C) Study of trapped specimens, 1979-1982.
Description - features.
Species Management - age/tech, kill/tech, harv/strategy.
Comments - Kits of both sexes can be reliably separated from other classes of lynx by pelt measurements, thus giving managers a method for monitoring recruitment at the fur-sale level; separation of other classes by pelt measurements is less clear although extra-large pelts are almost always from males.

Quinn, N.W.S., and G. Parker. In Press. Lynx. Chapter *in* M. Novak,J.A. Baker, M.E. Obbard, and B. Malloch (eds.). Wild furbearer management and conservation in North America. Ontario Trappers Assoc., North Bay.

101 A) 2; B) North America; C) Review of literature.
Description - features, taxonomy, distribution.

Habitat Characteristics - vegetation.
Life History - lifehist.
Population Dynamics - cycles, natality, mortality, popcomp, poptrend.
Species Management - age/tech, field/tech, economics, harv/strategy, transplants.
Habitat Management - hab/strategy.
Comments - This paper summarizes lynx biology and management based on the authors' management and research experience in eastern Canada, and are all listed elsewhere in the present bibliography. From the many topics covered some of the major points relating to management are as follows: In conifer-dominated habitats, dense softwoods with shrub openings of 2-4 ha are considered ideal for hares, and therefore for lynx hunting habitat; it is suggested that because lynx are relatively docile in traps, trappers can practice selectivity by releasing nontarget animals, e.g., adult females--some verbal instructions are given; it is noted that identifying kittens in fur samples may be the easiest way of monitoring population recruitment, but may not be the most reliable if trapping biases are not taken into account; factors managers should be aware of in setting seasons include "...differential vulnerabilities to trapping throughout the season, and the relationship of age, sex, and period of capture to pelt value."; the "minimum data set" for managing lynx populations include chronology of harvest statistics and hare abundance, carcass analyses in relation to harvest and hare data, annual lynx abundance indices, and keeping abreast of relevant literature; wildlife and forest practices producing small strip or block cuts are beneficial to hares and lynx, while extensive clearcutting "is unacceptable"; lynx were successfully introduced into southeastern Ontario in the 1950's (no details given).

Quinn, N.W.S., and J.E. Thompson. 1985. Age and sex of trapped lynx, *Felis canadensis*, related to period of capture and trapping technique. Can. Field-Nat. 99: 267-269.

102 A) 3; B) Ontario; C) Analysis of carcasses and harvest data, 1979-1982.
Life History - activity, behavior.
Population Dynamics - popcomp.
Species Management - age/tech, harvest, harv/strategy.
Comments - Age and sex composition of the harvest changed within the trapping season, with yearlings comprising a high proportion of the early harvest, kits increasing in January and February, and adults remaining a fairly constant proportion throughout; it is believed that males are more vulnerable to leg-hold trap sets that are females; the Ontario population was "rapidly increasing" at the time of the study, and it is acknowledged that the composition of the harvest at other phases of the cycle would differ from that observed.

Quinn, N.W.S., and J.E. Thompson. 1987. Dynamics of an exploited Canada lynx population in Ontario. J. Wildl. Manage. 51: 297-305.

103 A) 3; B) Ontario; C) Analysis of harvest data and 993 carcasses, 1979-1982.
Habitat Characteristics - study/area, vegetation.
Population Dynamics - natality, mortality, poptrend, popcomp.
Species Management - age/tech, kill/tech, repro, economics, harvest, harv/strategy.
Comments - Composition, estimated annual mortality, productivity, and physical condition of trapped lynx were compared in tow broad habitats (Boreal Mixed Wood and True Boreal Forest), and in three areas of differing harvest density (0.34, 0.70, and 1.71 lynx/100 km^0;

both hare and lynx populations were increasing during the study period; studied parameters varied little across the comparison areas; the 3-year harvest was characterized by an abundance of yearlings and was significantly dominated by males; it is concluded that males, especially the yearlings, are the most vulnerable to trapping; productivity was high, with almost all yearling and adult females and one-third of kittens having bred, and with average apparent litter size (placental scar counts) of 4.18; average annual mortality rates of 46% for males, 28% for females, and 38% overall were estimated, and it was noted that the population nevertheless increased at those rates.

Rasmussen, J.L. 1969. A recent record of the lynx in Iowa. J. Mammal. 50: 370-371.

104 A) 1; B) Iowa; C) Report of an animal shot in July 1963.
Description - distribution.
Life History - dispersal.
Comments - Male, believed young, 12.2 kg; this was the first documented occurrence for the state--the most recent previous record was a verbal report of a sighting in 1906.

Rogers, P.M. 1978. Predator prey relationship between rabbit and lynx in southern Spain. Terre et La Vie 32: 83-88.

105 A) 1; B) Spain; C) Food habits study based on analysis of 351 scats.
Life History - food.
Comments - Rabbit (*Oryctolagus*) was found in 84% of the scats, and ducks in 11%--deer, small mammals, and various birds also find, but in only minor amounts; it is suggested that lynx may be dependent on rabbits in that area of Spain, and that they may have evolved a relationship similar to that between lynx and hares in North America.

Rowan, W. 1954. Reflections on the biology of animal cycles. J. Wildl. Manage. 18: 52-60.

106 A) 1; B) Canada; C) Review of literature on the 10-year cycle.
Life History - food, dispersal.
Population Dynamics - cycles.
Comments - Disagreeing with Cole (1954), the author contends that the northern 10-year cycle is real, and that the clearest data on the subject are those relating to the historic pattern of lynx fur returns.

Saunders, J.K., Jr. 1961. The biology of the Newfoundland lynx (*Lynx canadensis subsolanus* Bangs). Unpubl. Ph.D Thesis, Cornell Univ., Ithaca, N.Y. 109pp.

107 *Comments* - Not seen; following papers are the formal elaboration of at least some thesis contents.

Saunders, J.K., Jr. 1963a. Food habits of the lynx in Newfoundland. J. Wildl. Manage. 27: 384-390.

108 A) 2; B) Newfoundland; C) Analysis of 206 digestive tracts and 220 scats, 1956-1961.

Life History - food, nutrition, behavior.
Comments - Snowshoe hare was the most used food throughout the year (73% occurrence), with highest use in winter and spring; other foods, especially microtines and birds, were most frequent in spring and summer, though still less than hares; carrion, mostly moose remains from the fall hunting season, was commonly used in winter; food requirements, and kills, amounted to the equivalent of about one hare every 2 days.

Saunders, J.K., Jr. 1963b. Movements and activities of the lynx in Newfoundland. J. Wildl. Manage. 27: 390-400.

109 A) 2; B) Newfoundland; C) Snow-tracking and live-trapping, 1956-1961.
Life History - activity, hmrange, movements, behavior.
Species Management - field/tech.
Comments - Most recaptures of tagged animals were within a few km of original capture sites although one animal, a male, dispersed 103 km after being resident for several months;three animals that travelled together in one winter proved to be an adult female with her two female kittens; daily movements ("cruising distances") averaged about 8 km, and the home ranges of the female with kittens and two males were, respectively, 15.5, 18.1, and 20.7 km^2; most activity occurred at night, but at a decreased level during storms.

Saunders, J.K., Jr. 1964. Physical characteristics of the Newfoundland lynx. J. Mammal. 45: 36-45.

110 A) 2; B) Newfoundland; C) Examination of trapped specimens.
Description - features.
Life History - pelage.
Species Management - age/tech.
Comments - Among animals over 1 year old, males were generally larger than females, but there were overlaps--mean weight for 93 males was 10.7 kg (range 6.4-17.2) and for 91 females was 8.6 kg (5.0-11.8); moult to winter pelage occurred by October and moult to summer pelage was in progress by April; some measurements on newborn and other very young animals are given; kittens may be distinguished by small body size and by deciduous or erupting permanent teeth; yearling females are almost as large as adult females; and have fully adult dentition by the end of their second year; yearling males are smaller than adult males, with only small sagittal crests and with the permanent lower canines not fully developed.

Schmidt, G.D. 1968. *Oncicola canis* (Kaupp, 1909)(Acanthocephala) from *Felis lynx* in Alaska. J. Parasitol. 54: 930.

111 A) 0; B) Alaska; C) Post-mortem examination of one specimen.
Life History - health.
Comments - 4 acanthocephalans were recovered from a lynx, but this paper focuses on the parasite, not the host; effects, if any, on the lynx are not described.

Schorger, A.W. 1947. Canada lynx taken in Sauk County, Wisconsin. J. Mammal. 28: 186-187.

112 A) 1; B) Wisconsin; C) Record of an animal shot, May 1946.
Description - distribution.
Life History - dispersal.
Comments - This animal, an adult male (12.2 kg) that had reportedly been present in the area for at least 2 years, was the first lynx taken in southern Wisconsin since 1907.

Schwartz, C.C., and E. Becker. 1987. Application of a probability sampling technique to estimate lynx density. *In* B. Townsend (ed.). Abstracts of Pap. Pres., Fourth Northern Furbearer Conference, 3-4 April 1987, Alaska Dep. Fish and Game, Juneau.

113 A) 3; B) Alaska; C) Radio-tracking, snow-tracking, and aerial surveys over a short time period.
Species Management - census.
Comments - Abstract only: The surveys yielded a density estimate that was "...accurate when related back to a known population of lynx whose numbers were based on concurrent radiotelemetry studies"; that density was 5.07±4.32 lynx/km^2.

Schwarz, E. 1938. Blue or dilute mutation in Alaskan lynx. J. Mammal. 19: 376.

114 *Comments* - not seen; cited in Tumlison (1987).

Shelford, V.E., and S. Olson. 1935. Sere, climax and influent animals with special reference to the transcontinental coniferous forest of North America. Ecology 16: 375-402.

115 A) 1; B) North America: C) Review of animal distribution.
Description - distribution.
Habitat Characteristics - vegetation, cover.
Habitat Management - fire, forestry.
Comments - In consideration of animals as indicators of forest associations within the coniferous forest biome of northern North America, the lynx is shown to occur in all three major subdivisions, the pine-hemlock association in the Great Lakes Region, the spruce-balsam fir association from the Atlantic west to the Rockies, and the spruce-pine association in the interior valleys of northern British Columbia, the Yukon and Alaska;though describing the lynx as "...a creature of the deep coniferous forests...(that)...like the marten retreats before the advance of the lumberman", the authors note that since it subsists largely on hares, it must do the bulk of its hunting in the swales of alder, willow, and black spruce occupied by its prey; "It can be said then that the lynx may live and die in the climax, it depends upon the subclimax for its food."

Siegler, H.R. 1971. The status of wildcats in New Hampshire. Pages 46-52 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minnesota.

116 A) 1; B) New Hampshire; C) Review of management status and information.
Species Management - harvest, refuges.

Comments - Based on bounty records and some personal communications from trappers, lynx had been rare in the state since at least the early 1930's; a closed area was established in the White Mountains National Forest in 1964.

Slough, B.G. 1986. Lynx status and management in the Yukon. Interim Rep., Yukon Dep. Renewable Resources, Whitehorse. 15pp.

117 A) 3; B) Yukon Territory; C) Literature review plus assembly of harvest and questionnaire data.
Population Dynamics - poptrend, popcomp.
Species Management - census, harvest, harv/strategy.
Comments - The most recent hare population crash was well-documented, with numbers dropping to 6% of peak densities within 2 years; trapping pressure is believed to have dropped in response to subsequent reduced lynx abundance, but there are concerns it may still be too high as a result of high fur prices; kittens comprised about 7% of the harvest in the fourth year after the hare decline, but with differences between areas (almost twice as many from Dawson as from Whitehorse); untrapped refugia are believed important during the cyclic low, and the only management change in recent years has been a shortening of the season from 5 to 4 months, eliminating March; a complete season closure during the low is recommended as "...the most biologically and economically sound management strategy over the long term."

Smith, C.H., and J.M. Davis. 1981. A spatial analysis of wildlife's ten-year cycle. J. Biogeogr. 8: 27-35.

118 A) 2; B) Canada; C) Re-analysis of historic lynx fur data.
Population Dynamics - cycles.
Comments - The 10-year periodicity of the lynx cycle is confirmed; data indicate that, in the 19th century, population trend reversals (increase or decline phases) commenced in about northern Alberta and spread from there roughly northward, and then to the south and east--the phase lag between the Athabaska region and northern Manitoba/Ontario was about 1.5 years; between the 1920's and mid-1970's, the "nodal region" has shifted 800 km or more to the east, to northern Saskatchewan and Manitoba; British Columbia apparently trails provinces from saskatchewan eastward by 2-4 years, is about 1 year behind Alberta, and precedes the Yukon by about 1 year.

Smith, J.D., E.M. Addison, D.G. Joachim, L.M. Smith, and N.W.S. Quinn. 1986. Helminth parasites of Canada lynx (*Felis canadensis*) from northern Ontario. Can. J. Zool. 64: 358-364.

119 A) 1; B) Ontario; C) Post-mortem examination of 317 lynx carcasses.
Life History - health.
Comments - 8 nematodes, 4 cestodes, and 1 trematode were found in the lungs and/or digestive tracts examined; 6 of the helminths (1 lungworm, 3 stomach/intestinal roundworms, and 2 taenids) were common, occurring in 22% to 92% of examined specimens--lynx are the exclusive definitive host of 5 of those, while the last also regularly

occurs in canids; no trend of negative effects on the condition of infected lynx was detected.

Spalding, D.J. 1971. The wildcats of British Columbia. Pages 60-67 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish. and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minnesota.

120 A) 2; B) British Columbia; C) Review of harvest records.
Species Management - harvest.
Comments - It is noted that the most common provincial harvests are around 2000 pelts, but the number was about 8000 in 1924 and 12 000 in 1962; the peaks are described as "...very abrupt and short-lived" with "...no relationship between these harvest fluctuations and number of trappers, or the price of furs"; it is speculated that sudden change in lynx numbers is the primary factor involved.

Stains, H.J. 1979. Primeness in North American furbearers. Wildl. Soc. Bull. 7: 120-124.

121 A) 2; B) North America; C) Review of literature and consultation with professional fur graders.
Life History - pelage.
Species Management - economics, harv/strategy.
Comments - Lynx are generally prime between about mid-November and the end of February, but are most prime in December and January.

Stephenson, R.O. 1984a. Development of lynx population estimation techniques. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., W-22-2, Job 7.12R, Juneau. 19pp.

122 *Comments* - Preliminary report: see Stephenson (1986).

Stephenson, R.O. 1984b. Development of lynx population estimation techniques. Alaska Dep. Fish and Game, unpubl. Pittman-Robertson Prog. Rep., W-22-3, Job 7.12R, Juneau. 5pp.

123 *Comments* - Preliminary report: see Stephenson (1986).

Stephenson, R.O. 1984c. The relationship of fire history to furbearer populations and harvest. Alaska Dep. Fish and Game, Unpubl. pittman-Robertson Final Rep., W-22-2, Job 7.13R, Juneau. 86pp.

124 A) 3; B) Alaska; C) 62 interviews, mostly trappers.
Habitat Characteristics - vegetation, cover.
Population Dynamics - poptrend.
Habitat Management - fire.
Comments - Most burns in the interior do not appear to support hares and lynx for the first 15 years post-fire, but they constitute significant habitat for those species 15-50 years post-fire; most respondents felt that lynx have an aversion to large expanses of open habitat, regardless of prey density;the Porcupine-Upper Yukon area in northeastern Alaska, which has a short fire cycle (43 years), is consistently one of the best lynx producers in the state--

"Both harvest records and trappers' comments indicate that lynx in this area reach higher densities and maintain these high densities for a longer time than in other areas."; fire suppression is currently extending the fire cycle in many parts of the state, and perhaps the subsequent reduction in younger successional forest stages may adversely affect lynx in the long term.

Stephenson, R.O. 1985. Development of lynx population estimation techniques. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., W-22-4, Job 7.12R, Juneau. 5pp.

125 *Comments* - Preliminary report: see Stephenson (1986).

Stephenson, R.O. 1986. Development of lynx population estimation techniques. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., W-22-2,3,4, job 7.12R, Juneau. 84pp.

126 A) 3; B) Alaska; C) Radio-tracking, aerial and ground transects, scat analysis, necropsy of carcasses, interviews, analysis of harvest data.
Habitat Characteristics - vegetation.
Life History - food, activity, hmrange, socbehav, movements, dispersal, health, denning, behavior.
Population Dynamics - natality, mortality, poptrend, popcomp, cycles.
Species Management - census, age/tech, repro, harvest, harv/strategy.
Comments - The studies were undertaken during the decline and low phase of the hare cycle; one male and two female lynx spent a combined total of about 65% of their time inactivity and 35% resting; home ranges for 5 of 6 animals were fairly stable, averaging 77 to 121 km^2 (based on 95% and 100% of locations, respectively); some shifts in home range over time were noted; one animal, a female, dispersed a minimum of 169 km from a range used for at least 2 months prior to the dispersal; lynx used a variety of habitats, perhaps mostly in relation to availability, although large openings were avoided; mating activity peaked during about the third week of March; there is evidence that the hare and lynx peaks in the early 1980's were considerably lower than the previous three peaks, and populations in the mid-1980's were very low; estimated densities in various sections of the study area were comparable to those obtained during the cyclic low in other areas, ranging from 1 lynx/17.4 km^2 to 1 lynx/69.4 km^2; the author feels that aerial and/or ground transects to record lynx tracks in snow have good potential for providing indices of lynx abundance, and explicit descriptions and instructions are provided; kittens were rare in Alaskan fur harvests between 1982 and 1985, coinciding with the local hare low as in other areas; none of 40 animals were over 4 years old, possibly reflecting previous poor production and/or heavy trapping pressure; a large proportion of the animals caught by trappers during the study, almost 50%, were judged to have been in less than good condition; analysis of reproductive tracts "...revealed a low rate of ovulation and breeding compared with rates during periods of hare abundance"; snowshoe hares were the most used food items, occurring in 70% or more of study samples, while microtine rodents, birds and red squirrels were also used commonly; several instances of predation (on red foxes, caribou and Dall's sheep) are documented.

Stewart, R.R. 1973. Age distribution, reproductive biology and food habits of Canada lynx (*Lynx canadensis*) in Ontario. Unpubl. M.Sc. Thesis, Univ. Guelph, Guelph, Ontario. 61pp.

127 *Comments* - not seen: Cited in most recent papers on population dynamics of lynx, e.g., Ward and Krebs (1985), Quinn and Thompson (1987).

Sweeney, S. 1977. A contribution towards an annotated bibliography on the bobcat (*Lynx rufus*) and Canada lynx (*Lynx canadensis*). Pages 1-55 *in* R.J. Poelker (ed.). Survey of native cats of Washington. Fed. Aid in Wildl. Restoration Proj. W-84-R-1, job 1, Univ. Washington, Seattle.

128 A) 2; B) North America; C) Review of existing literature.
Other Topics - bibliography.
Comments - This is an annotated bibliography for literature on the genus through the mid-1970's, organized by the following topics: 1) food habits, predation, hunting activity of bobcats, 2) trapping, hunting, capture and immobilization techniques, 3) general ecology, 4) population status/cycles, 5) economic status, 6) range, distribution, habitat, and movements, 7) behavior, reproduction, aging, 8) parasites, disease, 9) taxonomy, and 10) miscellaneous.

Todd, A.W. 1983. Dynamics and management of lynx populations in Alberta. Rep., Alberta Fish and Wildl. Div., Edmonton. 23pp.

129 *Comments* - Not seen: Cited in O'Connor (1984).

Todd, A.W. 1985. The Canada lynx: ecology and management. Canadian Trapper 13(2): 15-20.

130 A) 3; B) Canada, mostly Alberta; C) Summary of current knowledge for the layman.
Life History - lifehist.
Population Dynamics - poptrend, popcomp, cycles.
Species Management - economics, harvest, harv/strategy.
Other Topics - history.
Comments - This is not a report of original research, but is a good, thoughtful summary of the lynx management problem, with emphasis on the Alberta situation; the effect of high pelt prices in increasing and intensifying trapping pressure is emphasized--it is noted that although average prices have been very high in the 1980's, top prices of more that $1000 better illustrate the incentive value of trapping for lynx even when they are scarce; most illustrations of population trends are based on harvest records, with additional reference to results of the Rochester studies for recent decades in Alberta; it is believed that declines in lynx harvest in the early decades of this century were due to overexploitation at around the turn of the century, and that continued low harvests in the 1940's and 1950's were due at least in part to very low prices and demand; the great harvest increases in the 1960's and 1970's cycles are attributed to recovered populations and increased prices, while the decline in the 1980's is thought due primarily to overexploitation as a result of greatly increased interest in lynx trapping during the previous decades--alternate explanations that might explain part of the recent harvest decline include permanent (agriculture) and temporary (fire, logging, succession) habitat losses, industrial development impacts, effects of a severe winter (1981-82) on the animals and/or on trappers, and smaller hare population levels; the

author makes a case for "progressive management" involving, at least, shortened or closed seasons during years of declining and low populations, and compulsory inspection and registration of pelts.

Tong, H. 1977. Some comments on the Canadian lynx data. J. Royal Stat. Soc. A, 140: 432-436.

131 A) 0; B) Canada; C) Mathematical analysis of historic lynx harvest data.
Population Dynamics - cycles.
Comments - This paper focuses on mathematical analysis methods rather than on the biological phenomena involved.

Tumlison, R. 1987. *Felis lynx*. Mammalian Species No. 269, Amer. Soc. Mammalogists. 8pp.

132 A) 2; B) Holarctic; C) Review of existing literature.
Description - features, taxonomy, distribution.
Habitat Characteristics - vegetation.
Life History - lifehist.
Population Dynamics - natality, mortality, poptrend, popreg, cycles.
Species Management - age tech. economics, harvest, harv/strategy.
Habitat Management - hab/strategy.
Other Topics - bibliography, paleontology, zoogeography, physiology, genetics.
Comments - Management-related information is as reviewed from other papers in the present bibliography.

Van Zyll de Jong, C.G. 1963. The biology of the lynx, *Felis (Lynx) canadensis* (Kerr) in Alberta and the Mackenzie District, N.W.T. Unpubl. M.Sc. Thesis, Univ. Alberta, Edmonton. 76pp.

133 *Comments* - Not seen: following papers are the formal elaboration of at least some of the thesis contents.

Van Zyll de Jong, C.G. 1966a. Food habits of the lynx in Alberta and the Mackenzie District, N.W.T. Can. Field-Nat. 80: 18-23.

134 A) 2; B) Alberta and NWT; C) Analysis of 75 digestive tracts (52 winter and 23 summer).
Life History - food.
Comments - In terms of frequency of occurrence, snowshoe hare was the most common item in winter (72%) and in summer (52%); microtines were important in both seasons, at 10% in winter (all *Microtus*) and 31% in summer (22% *Microtus* and 9% *Clethrionomys*); other mammals eaten included red squirrel, two species of ground squirrel, beaver, and deer; birds occurred in 23% of winter tracts (10% grouse and 13% unidentified) and in 35% of summer samples (4% grouse, 4% Gray Partridge, 9% duck, and 17% unident.); the lynx population was believed high and the snowshoe hare still relatively high, but declining, when the samples were obtained.

Van Zyll de Jong, C.G. 1966b. Parasites of the Canada lynx, *Felix* (*Lynx*) *canadensis* (kerr). Can. J. Zool. 44: 499-509.

135 A) 1; B) Alberta, NWT; C) Necropsies of 113 carcasses and examination of 15 live animals.
Life History - health.
Comments - The specimen collection was made in 1961-1963, during a "high" in the lynx population; parasites in the small intestine included 4-5 species of cestodes (mostly *Taenia*), 1 trematode, and 2 species of nematodes, at infection rates ranging from 1 (the trematode *Alaria*) to 85% (*Taenia laticollis*); all other endoparasites were nematodes, 2 species from the stomach and 1 in the lungs; only 3 of 113 animals had no endoparasites; no ectoparasites were found on 18 animals examined, but a flea normally found on red squirrel was provided separately from a hunter-shot lynx; there was no indication that any of the lynx examined were adversely affected by their parasite loads.

Van Zyll de Jong, C.G. 1971. The status and management of the Canada lynx in Canada. Pages 16-22 *in* S.E. Jorgensen and L.D. Mech (eds.). Symposium on the native cats of North America. U.S. Bur. Sports Fish. and Wildl., Fed. Bldg., Fort Snelling, Twin Cities, Minnesota.

136 A) 2; B) Canada; C) Review of information from provincial and territorial sources.
Description - distribution.
Population Dynamics - poptrend.
Species Management - harvest.
Other Topics - history.
Comments - It is noted that the species' range expands temporarily during years of abundance, but that its true range should be considered as that area supporting animals both during the highs and lows of the cycle; the species still occurs over most of its pristine range in Canada, although it is rare or absent in heavily developed areas to the south, and it is essentially extinct in New Brunswick, Prince Edward Island, and possibly mainland Nova Scotia; bases on historic fur records, it is noted that production during peak years between 1820 and 1919 ranged from 30 000 to 80 000 pelts, but that declines occurred there after, especially in the 1940's and 1950's when, ti is said, "...populations failed to peak in most parts of Canada."--both over trapping and habitat changes have been implicated; at date of writing, lynx were managed as fur animals, with closures during seasons when pelts are not prime, in all jurisdictions except Newfoundland (no closed season; control as predator in some caribou calving areas); it is noted that in the larger provinces "...trapping is largely on registered traplines which tends to reduce trapping pressure: and there was additional management in Ontario in the form of quotas; the potential for over-harvest during the cyclic low is discussed, citing evidence from "...southern, more intensively trapped registered traplines and unorganized trapping areas" which now apparently depend mostly on immigration from other areas; it is suggested that should more intensive management be required in the future, it should be "...geared to the different phases of the cycle" (and) "...protection during (population) troughs should be considered in at least some areas."

Van Zyll de Jong, C.G. 1975. Differentiation of the Canada lynx *Felis canadensis sobsolana* in Newfoundland. Can. J. Zool. 53: 699-705.

137 A) 0; B) Newfoundland; C) Examination of museum specimens.
Description - features, taxonomy.
Comments - The Newfoundland lynx differs somewhat front the mainland form occurring over the rest of the continent in both cranial characters and in color ("richer,darker"), but differences are not considered sufficient to justify subspecific separation.

Ward, R.M.P. 1985. Behavioral responses of lynx to declining snowshoe hare abundance. Unpubl. M.Sc. Thesis, Univ. of B.C., Vancouver. 106pp.

138 A) 3; B) Yukon; C) Radio-tracking (6 males, 5 females) over a 2+ year period, plus snow-tracking.
Life History - food, hmrange, socbehav, movements, dispersal,health.
Population Dynamics - mortality, poptrend, cycles, popreg.
Species Management - harvest, harv/strategy.
Comments - Lynx biology described in relation to snowshoe hare abundance (decline phase only); see Ward and Krebs (1985), below; the author notes that although study results to date are suggestive, showing high rates of trapping mortality among study animals and indicating particular vulnerability to trapping during the low in the hare cycle, there are still some important inconsistencies and data gaps.

Ward, R.M.P. 1987. The lynx harvest: are refugia maintaining lynx populations? *In* B. Townsend (ed.). Abstracts of Pap. Pres., Fourth Northern Furbearer Conference, 3-4 April 1987, Alaska Dep. Fish and Game, Juneau.

139 A) 3; B) General; C) Computer modelling of population dynamics data from the literature.
Population Dynamics - poptrend, cycles.
Species Management - harvest, harv/strategy.
Comments - Abstract only: The model developed supports concerns expressed by wildlife managers in relation to the potential for overexploitation of lynx populations during the cyclic low; simulated lynx populations went to extinction at sustained harvest rates of more than 34% for 10 years, but with closures during 3 years of the low, a harvest rate of 41% could be applied for the remaining 7 years of the cycle; it is noted, however, that human-related mortalities based on radio-collared samples (81% of all studies combined) is higher than recruitment during any stage of the cycle, thus suggesting that "...refugia from trapping may be maintaining and stabilizing lynx over large geographic areas."

Ward, R.M.P., and C.J. Krebs. 1985. Behavioural responses of lynx to declining snowshoe hare abundance. Can. J. Zool. 63: 2817-2824.

140 A) 3; B) Yukon; C) Radio-tracking plus snow-tracking transects (see Ward 1985, above).
Life History - food, hmrange, socbehav, movements, dispersal, health.
Population Dynamics - mortality, poptrend, cycles.
Species Managements - harvest, harv/strategy.

Comments - This is the published elaboration of the biology section in Ward (1985); following the crash of the Hare population, lynx home ranges increased 3-fold, from 13.2 to 39.2 km^2; home ranges did not differ significantly in size between the sexes, and overlapped considerably between and among sexes; at prey densities below about 0.5 hares/ha, some lynx (3 females) appeared to "...abandon their home ranges and become nomadic."; 3 of 7 collared animals dispersed more than 250 km, up to 700 km, during the rapid decline phase of the hare cycle in 1982--those movements were during the May-October (snowfree) period; no such dispersals were recorded among 4 newly collared animals the following year, when hare densities, though low, had stabilized; daily movements of collared lynx were 2.2-2.7 km/day at hare densities above 1.0 hare/ha, but increased to 5.5 km /day at densities below that; it is concluded that the observed increased activities, range sizes, and dispersal were behavioral responses to the hare decline, to enable individuals to meet their energetic requirements; only 3 of the 11 collared animals survived for more than 1 year--the 8 losses included 7 animals taken by trappers outside the study area and 1, a female, that is believed to have starved in winter 1983-84; only 1 of 9 animals that left the study area, where human harvest is prohibited, is believed to have survived; it is noted that lynx are probably most vulnerable to trapping during the hare decline, when they are both hungry (thus more likely to be attracted to baits) and mobile (thus more likely to contact traps), and that they are probably therefore particularly sensitive to overharvesting at such times.

Ward, R.M.P., and B.G. Slough. 1987. Lynx management progress report, 1986/87. Pages 33-56 *in* B.G. Slough, and R.M.P. Ward. Annual Prog. Rep., Furbearer Manage. Program, Yukon Dep. Renewable Resources, Whitehorse.

141 A) 3; B) Yukon; C) Analysis of harvest data; telemetry.
Habitat Characteristics - study area.
Population Dynamics - natality, poptrend, popcomp.
Species Management - census, field/tech, harvest.
Comments - Harvest declined 24% from the previous year, but populations of both lynx and hares were considered at least stable; based on pelt measurements, the proportion of kittens increased slightly, to 9.3% overall, with the Dawson sample still showing twice the kitten proportion as that from the Whitehorse area; telemetry data indicate that "refugia...are producing a surplus of lynx for the 'traplines'"; telemetry studies have begun in the Teslin burn area to assess the role of refugia, determine the nature of trapping mortality in relation to natural mortality, monitor lynx recruitment in relation to hare abundance, and develop techniques for monitoring lynx populations; a total of 6 lynx (4 males, 2 females) have been radio-collared, and all but one of the males has remained in the study area; both females produced litters--3 and 4 kittens, all of which were ear-tagged; population density will be assessed by a track transect method.

Weinstein, M.S. 1977. Hares, lynx, and trappers. Am. Nat. 111: 806-808.

142 *Comments* - Not seen: cited in Finerty (1969), as questioning whether lynx cycles as measured by harvest data are more artifacts of differential trapper activity that of biological phenomena.

Werdelin, L. 1981. Evolution of lynxes. Ann. Zool. Fenn. 18: 37-71.

143 A) 1; B) Holarctic; C) Examination of specimens; review and analysis of published data.
Description - taxonomy.
Other Topics - paleontology, zoogeography, evolution.
Comments - The genus *Lynx* is considered to be of African origin, first appearing in the early to mid-Pliocene (2.5 million years ago); the North American species is believed to have descended from the European species within the past 200 000 years, and has changed little since it first appeared--the bobcat is believed to have arisen from a separate ancestor that arrived in North America much earlier; in general there is little sexual dimorphism within the genus.

Wiig, O., and T. Anderson. 1986. Sexual size dimorphism in the skull of Norwegian lynx. Acta Theriol. 31: 147-155.

144 A) 0; B) Norway; C) Examination of specimens.
Description - features.
Comments - Males are larger than females in various skull measurements by about 6-7%.

Wilson, M. 1969. Predation on woodchuck by Canada lynx in British Columbia. Blue Jay 27: 160.

145 A) 1; B) British Columbia; C) Note on stomach contents of 1 lynx.
Life History - food.
Comments - The lynx ate, but did not necessarily kill, a *Marmota* individual for which species was not positively identified, but was assumed to be *monax*; season unknown.

Wing, J.F. 1982. On the predictability of reversals in solar terrestrial correlations. Ohio J. Sci. 82: 100.

146 A) 0; B) General; C) Correlation of solar events with population cycles.
Population Dynamics - cycles.
Comments - Abstract only: historic lynx fur return data are said to support a contention that "...breakdowns and reversals in solar-terrestrial correlations are due to solar events themselves."

Wing, J.F., K. Peterson, and K.M. Anderson. 1985. Snowfall as a contributing cause of the 10-year cycle in the snowshoe hare. Ohio J. Sci. 85: 93.

147 A) 1; B) North America; C) Consideration of weather factors in relation to the hare-lynx cycle.
Habitat Characteristics - climate.
Population Dynamics - cycles.
Comments - Abstract only: "Moderate snowfall" is shown to have a 10-year cycle in Alaska, Canada, and the Lake states, and is correlated with measures of hare and/or lynx abundance in those areas; it is noted that "snowfall increases the quantity/quality of

vegetation at times of low hare density, and moderate snowfall also provides cover and warmth while permitting browse."

Wing, L.W. 1935. Wildlife cycles in relation to the sun. Trans. North Am. Wildl. Conf. 21: 345-363.

148 *Comments* - Not seen.

Wing, L.W. 1953a. A composite index of lynx abundance, 1735-1950. J. Cycle Res. 2: 21-24.

149 A) 1; B) Northern Canada; C) Consideration of historic lynx fur returns.
Population Dynamics - cycles.
Comments - This is an attempt to "correct" previous figures on historic lynx harvests on the basis of economic, social, and other factors that might have influenced reports (and not just harvest levels).

Wing, L.W. 1953b. Cycles of lynx abundance. J. Cycle Res. 2: 28-51.

150 A) 1; B) Northern Canada; C): Consideration of historic lynx fur returns.
Population Dynamics - cycles.
Comments - A detailed account of the nature of mathematical cycles, and discussion of the lynx harvest cycles in that context; an average cycle length of 9.6 years calculated for the lynx data.

Winterhalder, B.P. 1980. Canadian fur bearer cycles and Cree-Ojibwa hunting and trapping practices. Am. Nat. 115: 870-879.

151 A) 1; B) Canada; C) Review of historical and anthropological literature.
Population Dynamics - cycles.
Species Management - harvest.
Comments - Acknowledging that recent biological studies have confirmed the existence of the hare-lynx cycle, the author nevertheless questions the accuracy of early lynx fur return data in defining and quantifying historic trends; evidence is presented showing that during hare lows, native trappers were often forced into devoting most of their energies into food gathering, and often ceased or greatly reduced hunting for fur at those times.

* * * * *

SUBJECT INDEX

The following index is organized under the descriptive elements characterizing aspects of the literature assembled (A), and by the subject headings and keywords relating to contents of that literature (B), all as described under "format" (section 3.2). For that topic, the number (N) and frequency of its occurrence (%) among the total papers indexed (T) are given in parentheses. The three digit identification numbers are those preceding the individual bibliographic entries in section 3.3.

A) CHARACTERISTICS OF THE LITERATURE

Geography (T=151): Locations of the observations, studies, and analyses reported.

Holarctic (N=5. 3.3%) 041, 068, 077, 132, 143.

North America, general (N=13, 8.6%)
032, 033, 036, 050, 061, 070, 083, 084, 101, 115, 121, 128, 147.

Canada, general (N=21, 13.9%)
005, 023, 026, 027, 037, 043, 046, 047, 048, 057, 082, 106, 118, 130, 131, 136, 142, 148, 149, 150, 151.

Provinces and Territories (N=51, 33.8%)
Alberta (N=13, 8.8%)
018, 019, 062, 071, 088, 089, 090, 095, 129, 130, 133, 134, 135.

Newfoundland (N=8, 5.3%) 014, 025, 054, 073, 107, 108, 109, 137.

British Columbia (N=8, 5.3%) 002, 007, 021, 035, 049, 096, 120, 145.

Ontario (N=7, 4.6%) 042, 080, 100, 102, 103, 119, 127.

Northwest Territories (N=6, 4.0%) 006, 022, 028, 085, 133, 134.

Yukon Territory (N=4, 2.7%) 117, 138, 140, 141.

Manitoba (N=3, 2.0%) 029, 066, 078.

Nova Scotia (N=2, 1.3%) 093, 094.

Quebec (N=2, 1.3%) 040, 072.

Saskatchewan (N=2, 1.3%) 004, 076.

United States (N=39, 25.8%)

Alaska (N=18, 11.9%)

003, 008, 009, 010, 011, 015, 016, 024, 086, 091, 111, 113, 114, 122, 123, 124, 125, 126.

Minnesota (N=5, 3.3%) 051, 075, 079, 080, 081.

Washington (N=4, 2.7%) 020, 063, 064, 087.

Montana (N=3, 2.0%) 013, 065, 087.

Wisconsin (N=3, 2.0%) 039, 060, 112.

Oregon (N= 2, 1.3%) 031, 087.

(N=1, 0.7%):

Idaho - 087; Iowa - 104; Michigan - 044; Nebraska - 030; New Hampshire - 116; North Dakota - 001; Wyoming - 053.

Eurasia (N=14, 9.3%)

Country unidentified (N=3, 2.0%) 012, 055, 062.

Norway (N=3, 2.0%) 017, 045, 144.

(N=2, 1.3%): Sweden - 045, 052; Finland - 098, 099.

(N=1, 0.7%): France - 056;Poland - 074;Spain - 105;USSR - 058; Yugoslavia - 034.

General--No specific location (N=7, 4.6%) 038, 059, 067, 092, 097, 139, 146.

Management Significance (T=133): Papers were subjectively rated as having high, medium, low, or nil significance in terms of implications for management; only highs and mediums are listed below.

High (N=32, 24.1%)

003, 009, 010, 011, 018, 019, 020, 026, 027, 047, 063, 064, 078, 081, 088, 090, 091, 092, 093, 094, 100, 102, 103, 113, 117, 124, 126, 130, 138, 139, 140, 141.

Medium (N=36, 27.1%)

004, 007, 008, 014, 015, 016, 029, 034, 035, 036, 037, 038, 043, 049, 051, 058, 059, 061, 062, 065, 077, 079, 086, 089, 096, 101, 108, 109, 110, 118, 120, 121, 128, 132, 134, 136.

Primary Study Methods (T=133):

Field (outdoor) Studies (N=46, 34.6%)

Telemetry (N=14, 10.5%)

009, 010, 011, 016, 020, 029, 063, 064, 065, 080, 081, 126, 138, 140.

Multi (several methods, N=7, 5.3%) 090, 094, 122, 123, 125, 126, 141.

Snow-tracking (N=7, 5.3%) 019, 052, 058, 088, 093, 096, 109.

Incidental Observations (N=14, 10.5%)
013, 014, 031, 034, 039, 042, 044, 051, 053, 054, 079, 104, 112, 145.

Other (1 drug testing, 1 tagging, 2 census = 4, 3.0%) 015, 089, 072, 113.

Laboratory Studies (N=29, 21.8%)
Harvest Samples Analysis (N=6, 4.5%) 086, 091, 100, 102, 103, 110.

Post-mortem Examinations (N=10, 7.5%)
002, 018, 025, 030, 071, 075, 095, 111, 119, 135.

Food Habits Studies (scats, digestive tracts, N=5, 3.8%) 085, 098, 105, 108, 134.

Museum Specimens Analyses (N=4, 3.0%) 068, 137, 143, 144.

Other Laboratory Studies (N=4, 3.0%) 059, 067, 073, 074.

Indoor (Paper) Studies (N=57, 42.9%)
Review, Synthesis Papers (N=40, 30.1%)
001, 003, 004, 007, 008, 024, 026, 027, 035, 036, 037, 041, 043, 045, 046, 047, 048, 049, 057, 060, 061, 070, 076, 077, 078, 082, 083, 087, 101, 106, 115, 116, 117, 118, 120, 121, 130, 132, 136, 151.

Cycles Analysis (Mathematics, N=12, 9.0%)
005, 006, 022, 023, 028, 032, 033, 131, 146, 147, 149, 150.

Population Modelling (N=3, 2.3%) 038, 092, 139.

Bibliography (N=2, 1.5%) 050, 128.

Interview (N=1, 0.8%) 124.

B) BIOLOGY AND MANAGEMENT OF THE LYNX: SUBJECT HEADINGS AND KEYWORDS (T=133)

Description (N=31, 23.3%): Aspects of the physical and geographical identity of the species.

Features (N=15, 11.3%)
029, 031, 039, 044, 052, 064, 068, 077, 094, 100, 101, 110, 132, 137, 144.

Taxonomy (N=6, 4.5%)
068, 077, 101, 132, 137, 143.

Distribution (N=24, 18.1%)
001, 003, 031, 036, 037, 039, 043, 044, 051, 053, 063, 064, 072, 077, 079, 080, 087, 094, 101, 104, 112, 115, 132, 136.

Habitat Characteristics (N=25, 18.8%)

Study/Area (N=11, 8.3%)
010, 016, 019, 029, 062, 064, 065, 093, 094, 103, 141.

Vegetation (N=16, 12.0%)
003, 010, 016, 047, 049, 058, 064, 077, 093, 094, 101, 103, 115, 124, 126, 132.

Cover (N=8, 6.0%) 003, 058, 064, 065, 093, 094, 115, 124.

Climate (N=6, 4.5%) 006, 047, 077, 088, 093, 147.

Life History (N=66, 49.6%)

Lifehist (General Coverage, N=7, 5.3%)
003, 035, 049, 077, 101, 130, 132.

Food (N=27, 20.3%)
013, 014, 018, 019, 034, 052, 054, 058, 062, 063, 064, 070, 073, 085, 088, 090, 093, 094, 098, 105, 106, 108, 126, 134, 138, 140, 145.

Nutrition (N=7, 5.3%) 018, 019, 058, 090, 093, 094, 108.

Activity (N=8, 6.0%) 019, 052, 088, 093, 094, 102, 109, 126.

Hmrange (Home Range, N=16, 12.0%)
010, 016, 019, 020, 029, 052, 058, 064, 065, 081, 090, 094, 109, 126, 138, 140.

Socbehav (Social Behavior, N=10, 7.5%)
019, 020, 029, 061, 064, 074, 081, 126, 138, 140.

Movements (N=17, 12.8%)
010, 016, 019, 029, 034, 052, 065, 080, 088, 089, 090, 093, 094, 109, 126, 138, 140.

Dispersal (N=19, 14.3%)
001, 027, 034, 044, 051, 053, 070, 076, 079, 080, 081, 089, 091, 104, 106, 112, 126, 138, 140.

Health (N=15, 11.3%)
002, 018, 019, 025, 067, 071, 075, 094, 095, 111, 119, 126, 135, 138, 140.

Denning (N=6, 4.5%) 016, 052, 058, 064, 093, 126.

Pelage (N=2, 1.5%) 110, 121.

Behavior (N=14, 10.5%)
013, 019, 042, 052, 054, 058, 073, 074, 093, 094, 102, 108, 109, 126.

Population Dynamics (N=72, 54.1%)

Cycles (N=42, 31.6%)
005, 006, 018, 019, 022, 023, 026, 027, 028, 032, 033, 035, 037, 041, 043, 046, 047, 048, 049, 057, 061, 062, 070, 082, 083, 090, 091, 101, 106, 118, 126, 130, 131, 132, 138, 139, 140, 146, 147, 149, 150, 151.

Natality (N=22, 16.5%)
010, 016, 018, 019, 024, 029, 034, 052, 063, 064, 077, 081, 086, 090, 091, 092, 094, 101, 103, 126, 132, 141.

Mortality (N=16, 12.0%)
010, 011, 018, 029, 064, 065, 077, 081, 090, 094, 101, 103, 126, 132, 138, 140.

Popcomp (Sex and/or age composition, N=13, 9.8%)
010, 018, 020, 081, 092, 094, 101, 102, 103, 117, 126, 130, 141.

Poptrend (Population Numbers, densities, indices, N=43, 32.3%)
001, 003, 004, 008, 009, 010, 011, 016, 018, 019, 020, 024, 029, 034, 037, 045, 049, 058, 062, 063, 064, 072, 078, 079, 081, 087, 090, 091, 092, 094, 096, 101, 103, 117, 124, 126, 130, 132, 136, 138, 139, 140, 141.

Popreg (Population Regulation, limiting factors, N=6, 4.5%)
020, 061, 062, 090, 132, 138.

Species Management (N=56, 42.1%)

Census (Techniques, N=6, 4.5%) 019, 072, 113, 117, 126, 141.

Age/tech (Age determination techniques, N=11, 8.3%)
059, 077, 091, 094, 100, 101, 102, 103, 110, 126, 132.

Field/Tech (Field study methods, N=11, 8.3%)
015, 016, 018, 073, 077, 088, 093, 094, 101, 141.

Kill/Tech (Collecting and analyzing harvest data, N=3, 2.3%) 091, 100, 103.

Repro (Assessing productivity, N=6, 4.5%) 077, 090, 091, 094, 103, 126.

Economics (Fur value, depredations, N=15, 11.3%)
004, 010, 014, 018, 024, 045, 049, 077, 078, 091, 101, 103, 121, 130, 132.

Harvest (Nature, extent, and/or effects, N=38, 28.6%)
003, 004, 008, 009, 010, 016, 018, 024, 026, 029, 035, 036, 037, 049, 054, 058, 076, 077, 078, 081, 087, 091, 092, 094, 102, 103, 116, 117, 120, 126, 130, 132, 136, 138, 139, 140, 141, 151.

Interactions (Relationships with other species, N=2, 1.5%) 038, 094.

Harv/Strategy (Harvest options, recommendations, N=34, 25.6%)
003, 004, 007, 008, 010, 011, 014, 016, 018, 024, 026, 036, 038, 045, 049, 060, 077, 078, 087, 091, 092, 094, 100, 101, 102, 103, 117, 121, 126, 130, 132, 138, 139, 140.

Transplants (N=3, 2.3%) 034, 077, 101.

Refuges (Parks, management areas, N=4, 3.0%) 029, 045, 094, 116.

Habitat Management (N=15, 11.3%)

Fire (N=8, 6.0%) 003, 008, 010, 024, 047, 064, 115, 124.

Forestry (N=7, 5.3%) 024, 036, 037, 058, 064, 087, 115.

Other/Impacts (Effects of human developments other than forestry, N=6, 4.5%)
003, 007, 036, 037, 047, 060.

Hab/Strategy (Recommendations, prescriptions, N=3, 2.3%) 007, 101, 132.

Other Topics (N=12, 9.0%)

History (N=5, 3.8%) 005, 035, 036, 130, 136.

Bibliography (N=4, 3.0%) 050, 077, 128, 132.

Physiology, Morphology (N=4, 3.0%) 068, 074, 077, 132.

Evolution, Genetics, Paleontology (N=4, 3.0%) 068, 077, 132, 143.

Zoogeography (N=3, 2.3%) 068, 132, 143.

* * * * *

APPENDIX A. Some literature of the biology of the snowshoe hare.

As the primary prey of the lynx over most, if not all of its North American range, the snowshoe hare is of particular interest in the context of lynx management. Aspects of hare ecology and population dynamics are presented in a number of the papers assembled for the lynx bibliography (Part 3). Following are the identification numbers of those papers, and a partial bibliography of additional hare references:

001, 004, 010, 018, 019, 022, 023, 027, 032, 033, 041, 043, 047, 048, 057, 058, 061, 062, 065, 070, 072, 088, 101, 106, 115, 117, 118, 138, 140, 141, 142, 146, 147, 148.

Adams, L. 1959. An analysis of a population of snowshoe hares in northwestern Montana. Ecol. Monogr. 29: 141-170.

Bider, J.R. 1961. An ecological study of the hare, *Lepus americanus*. Can. J. Zool. 39: 81-103.

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